



Girls Doing Science: A Case Study of Science Literacy in All-Female Middle Grade Classrooms

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Girls Doing Science:
A Case Study of Science Literacy in All-Female Middle Grade Classrooms

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A Thesis Presented to the Faculty
of the Graduate School of Education of Harvard University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Education

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This thesis is dedicated to Ms. Marsh and all of the Lyon Academy students.

Watching you teach, learn, and grow has been a privilege.

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Table of Contents

Thesis Abstract.....	vi
Chapter I: Thesis Introduction.....	1
References.....	12
Chapter II: Study 1	
<i>Literacy Practices and Text Genres in Girls' Middle Grade Science Classrooms</i>	
Abstract.....	17
Introduction.....	19
Background Literature: Literacy in Science.....	21
Present Study.....	27
Study Design and Methods.....	28
Findings.....	34
Discussion.....	40
References.....	47
Tables and Figures.....	51
Chapter III: Study 2	
<i>Shaping Girls' Science Identity: Exploring the Role of Classroom Experiences and Popular Images</i>	
Abstract.....	64
Introduction.....	66
Theoretical Framework.....	67
Study Design and Methods.....	74
Findings.....	80

Discussion.....	96
Limitations and Directions for Future Research.....	99
References.....	102
Tables and Figures.....	107
Appendix: Mapping of Questions from Student Interview Protocol to Three Facets of Science Identity.....	113
Chapter IV: Study 3	
<i>Who Does Science?: Science Attitudes and Identity among Middle Grade Students at a Small All-Girls' School</i>	
Abstract.....	115
Introduction.....	117
Theoretical and Empirical Perspectives on Science Identity.....	119
Study Design and Methods.....	126
Findings.....	132
Discussion.....	152
Implications for Practice.....	157
Limitations and Directions for Future Research.....	159
References.....	161
Tables and Figures.....	166
Appendix A: Full Student Interview Protocol.....	169
Appendix B: Full Student Survey.....	181
Vita.....	190

Thesis Abstract

In the face of low adolescent literacy rates (NCES, 2012), concerns about the nation's prospects of remaining competitive in science and technology (Hill, Corbett, & St. Rose, 2010), a persistent gender gap in science (NCES, 2012; Reilly, 2012), and the continued rollout of college- and career-ready standards, there is a need to focus on adolescent girls' science literacy. Such science literacy involves not only general knowledge about science, but also the ability to engage in the advanced reading and writing practices fundamental to doing science (Norris & Phillips, 2003). In this thesis, I present three articles with findings that respond to this need. They are the results of a multiple-case embedded (Yin, 2009) study that I conducted over the course of 7 months in four science classrooms (grades 5 through 8; 50 students) taught by a single teacher in a small all-female middle school. I collected in-depth data focused on science literacy from multiple sources, including (a) fieldnotes (Emerson, Fretz & Shaw, 2011), (b) videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), (c) a survey of all students, (d) semi-structured interviews with the subsample of 12 focal students (ranging from 18 to 37 minutes) and (e) photographs of classroom artifacts and student work.

In the first article, I provide a window into standard literacy practices in science classrooms by examining the reading and writing genres to which students are exposed. In the second article, I examine how a teacher's language and instructional practices within her classrooms, and popular images of science from the world beyond their classrooms might shape adolescent girls' science identities. Finally, in the third article, I explore different aspects of science identity using the words of three case study students.

Taken together, these studies fill gaps in the literature by investigating science literacy in an understudied context, all-female classrooms. In addition, they give voice to a group often underrepresented in studies of science (i.e., primarily nonwhite girls from working class families, many of whom speak English as a second language.) Thus this thesis provides new insights for researchers as well as teachers interested in science literacy and persistent gaps in science achievement.

Chapter 1: Introduction

Educators are increasingly asked to foster advanced literacy in *all* adolescents, preparing a citizenry ready to engage in meaningful ways with the 21st century demands for knowledge production and transformation (Carnegie Council on Advancing Adolescent Literacy, 2010). Moreover, some highlight the special place of science literacy, arguing that the strength of the U.S. economy relies on our ability to prepare leaders in the fields of science, technology, engineering, and mathematics (STEM) (Hill, Corbett, & St. Rose, 2010). Yet, the results of the National Assessment of Education Progress (NAEP) indicate that most adolescents lack the advanced reading, writing, and science skills necessary for knowledge production and transformation (National Center for Education Statistics (NCES), 2012). Moreover, in the specific case of science, only 32% of 8th graders perform at or above the proficient level and a mere 2% reach the advanced level (NCES, 2012). Even more troubling is the small but persistent gender gap in science achievement favoring males (NCES, 2012; Reilly, 2012), along with the underrepresentation of females in STEM professions (Hill, Corbett, & St. Rose, 2010). While female high school students now earn math and science credits at the same rate as males and receive slightly higher grades in these courses (NCES, 2007), females still lag far behind males in areas such as the pursuit of STEM degrees and representation in STEM workplaces (Hill, Corbett, & St. Rose, 2010). Taken together, these findings indicate that social and cultural mechanisms other than broad patterns of access influence females' views of science literacy and whether or not they pursue STEM fields beyond high school.

The disciplinary literacy perspective provides a promising framework for understanding these social and cultural mechanisms. From this perspective, reading, writing, and oral language can be understood as social practices that vary across different contexts, cultures, and academic disciplines. Advanced literacy involves much more than decoding and understanding print; it also includes coming to understand and participate in discipline-specific norms of practice, conventional ways of interacting and communicating (including reading and writing), as well as representing, defending, and challenging knowledge (Moje, 2008). For example, a frequently cited norm of practice in the case of science is the convention of supporting all claims with particular types of evidence, often empirical evidence from experiments. Such evidence may be markedly different from the evidence students are expected to provide when supporting historical or mathematical claims. Therefore, advanced literacy requires that students learn to take on the differing identities of members of each disciplinary community and engage in the literacy and language activities valued by that discipline (Shanahan & Shanahan, 2008).

Currently, induction into discipline-specific literacy practices is implicit in most content area classrooms. However, the continued rollout of new rigorous college- and career-ready standards, such as the *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects* (CCSS; Common Core State Standards Initiative, 2010) is likely to result in greater numbers of content area teachers being asked to take a more active and explicit role in teaching their students how to read, write, and communicate in discipline-specific ways. Given this context, there is a pressing need to develop a deeper understanding of the current literacy practices, including the ways in which students' disciplinary-identities are shaped, in

science classrooms in order to identify promising areas to focus on. This issue is especially critical for students who have traditionally been underrepresented in the discipline.

In this thesis, I begin to address these needs through three related studies of science literacy among adolescent girls ($n=50$) at the Mary Lyon Academy for Girls¹ (Lyon Academy), a small all-female middle school that largely serves students from working class backgrounds and students of color. Because it is a small school, all science classes are taught by a single teacher, Ms. Marsh. In the first study, I used quantitative and qualitative analysis of observational data to document the reading and writing practices and text genres found in Ms. Marsh's classrooms to provide insight into science literacy practices. The second and third studies then focus on science identity. In the second study, I used qualitative analysis of classroom observations and interviews with a subsample of 12 focal students to examine the ways in which adolescent girls' views of science identity were shaped by two primary factors: their teacher's language and instructional practices within their classrooms, and popular images of science from the world beyond their classrooms. Finally, in the third study, I used quantitative analysis of survey data from all students and qualitative analysis of interview data from three case study students to explore the Lyon Academy students' constructions of science identity in more depth.

In the following sections of this chapter, I briefly review the background literature that has helped to shape my thesis. I then suggest unanswered questions that my research begins to address. Next, I provide a brief overview of the three studies contained in my thesis. I end with a section outlining some of the implications of my work.

¹ All names are pseudonyms.

What Do We Know about Literacy in Science?

Literacy is Fundamental to Doing Science

Reading and writing texts that conform to discipline-specific norms are fundamental aspects of “doing science.” While definitions of science literacy sometimes focus on a general sense of knowledgeability in science rather than reading and writing, Norris and Phillips (2003) argue that in so doing they fail to address a constituent element of science literacy. In fact, in their view, reading and writing are fundamental to science:

[R]eading and writing do not stand only in a functional relationship with respect to science, as simply tools for the storage and transmission of science. Rather, the relationship is a constitutive one, wherein reading and writing are constitutive parts of science. Constitutive relationships define necessities because the constituents are essential elements of the whole. Remove a constituent, and the whole goes with it. Throw away the cover and keep the contents, and you still have a book; throw away the contents and keep the cover, and you no longer have a book (p. 226).

Put another way, one cannot participate fully in the investigatory aspects of science without having advanced literacy skills, such as the ability to interpret data arrays, understand precise discipline-specific vocabulary, read critically, and write discipline-appropriate explanations (Conley, 2008; Norris & Phillips, 2003; Osborne, 2002 as cited in Greenleaf et al., 2010 p. 649).

Literacy is Often Neglected in School Science

Traditionally, science teachers have paid little attention to teaching reading or writing (Wellington & Osborne, 2001). The best available evidence on reading and

writing instruction in typical science classrooms indicates that it occurs infrequently in middle and high school classrooms in the US (Applebee & Langer, 2009, 2011; Fisher, 2009; Kiuahara, Graham & Hawken, 2009). Although more empirical evidence is needed, available research suggests that reading in science is dominated by textbooks (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Moreover, and particularly relevant in light of the demands of college- and career- ready standards, students appear to have very few opportunities to write extended texts in science (Applebee & Langer, 2009, 2011; Kiuahara et al., 2009), including those within analytic genres (Lawrence, Phillips Galloway, Yim, & Lin, 2014). Norris and Phillips (2003) suggest that this lack of attention to literacy is due to the perception among science educators that their students should be able to comprehend texts as long as they can decode them.

Identities Matter

As Heath and Street (2008) point out, a major task from the adolescent's point of view is learning that different disciplines require them "to switch writing styles and genres between one setting and another, to deploy a repertoire of literacy practices appropriate to each setting, and to handle the social meanings and identities that each evokes" (p. 105). From this perspective, science identity—being recognized as the "kind of" person who does science" (Gee, 2001)—is a fundamental aspect of science literacy. A growing body of literature examines science identity among young people, and especially the interplay of gender, social class, ethnicity and identity (e.g., Archer et al., 2010; Archer et al., 2012; Carlone, Haun-Frank, & Webb, 2011; Carlone, Scott, & Lowder, 2014; Wong, 2012). This literature indicates that beliefs about science identity might be an important explanatory factor in considering the persistent

underrepresentation of certain groups in science. In particular, whether or not students view science as being for people “like them” appears to be an important factor (Archer et al., 2012; Archer et al., 2013; Wong, 2012). Such beliefs appear to be shaped by both classroom experiences (Carlone, Haun-Frank, & Webb, 2011; Carlone, Scott, & Lowder, 2014; Lemke, 1990; Moje, 1995) and popular discourses (ASPIRES, 2013; Archer et al., 2013; Wong, 2012) and images (Barman, 1997; Chambers, 1983; Reveles, 2009).

What Do We Still Need to Know?

Through my literature review, I identified several areas for further empirical work. First, although writing in content area classrooms is better documented than reading, there is a lack of knowledge about what kinds of texts students are reading and writing in their science classes (i.e., text genres) and what activities they are being asked to do with these texts (i.e., literacy practices). In particular, more information is needed on what, if any, texts students read in science classrooms besides course textbooks. At the same time, the studies of writing in science classrooms suggest that students are rarely asked to write extended text. Yet it is impossible to meet the challenge of college- and career-ready standards, such as the CCSS, without doing this. Therefore there is a need to focus on what opportunities students are given to write sophisticated informational texts. Next, the literature suggests the need for research to consider numerical and visual representations as well as text in order to understand the literacy work taking place in science classrooms. Finally, the disciplinary-literacy perspective highlights the need to teach discipline-specific reading and writing practices. Yet much of the work on disciplinary literacy remains conceptual and little is known about how, if at all, adolescents are taught to read and write like scientists (Fang & Coatoam, 2013). For

example, while we know that expert chemists critically examine the plausibility of scientific claims when they read (Shanahan, Shanahan & Misischia, 2011), we know very little about how adolescents are taught to read in this way. What little information we have about standard practice in middle and high school science classrooms describes general-school literacy practices (e.g., filling in worksheet, copying notes, reading textbook independently) rather than anything specific to the discipline of science. This points to a need for more research into which, if any, literacy practices in science classrooms appear to be specific to “doing science” rather than “doing school.”

Turning to identity, little is known about how adolescents in different classroom contexts are socialized into different views of science identity. Specifically, although it is not uncommon for proposals to address the underrepresentation of women in science to call for single-gender science classrooms, there is very little empirical work investigating how students in such settings construct science identity. Second, although classroom experiences (Carlone, Haun-Frank, & Webb, 2011; Carlone, Scott, & Lowder, 2014; Lemke, 1990; Moje, 1995) and popular images and discourses (ASPIRES, 2013; Archer et al, 2013; Barman, 1997; Chambers, 1983; Reveles, 2009; Wong, 2012) both appear to play an important role in shaping young people’s views of what it means to be the kind of person who does science, very little empirical work has examined these factors together. In addition, very few of the studies that link classroom experiences to student constructions of science identity have focused on racial/ethnic minority students, students from working class families, or students who speak English as a second language. Since these same groups are often underrepresented in the field of science, there is a need for more research that considers their perspectives. Finally, there is a relative lack of

empirical work that has attempted to systematically examine multiple aspects of science identity using quantitative and qualitative measures, exploring how different aspects of science identity may be constructed differently by the same adolescent.

The Present Studies

As a first step in generating the knowledge outlined in the previous section, I undertook a program of research at the Lyon Academy, a small all-female middle school, largely serving students from working class backgrounds and students of color. I selected the Lyon Academy as the study site for several reasons. First, while many proposals to address the gender gap in science call for single-gender science classrooms, there is very little empirical work investigating such settings. Second, the Lyon Academy primarily serves students whose voices are often absent from studies of science learning, and who are generally underrepresented in the field of science, namely females from working class backgrounds. Third, I conducted several preliminary visits to the classrooms before the study began where I saw the teacher, Ms. Marsh, use language that was interesting from the standpoint of disciplinary literacy. Indeed, during these observations, I noted the teacher's induction of students into science-specific ways of generating knowledge (e.g., "That's a claim by Ana, but we could actually test it. What's your evidence?") and promotion of scientific identities (e.g., "As scientists, we want some data on this."). Finally, Ms. Marsh expressed interest in literacy development, but had relatively little knowledge about it, indicating the potential for her and her students to benefit from my research findings.

In the overall research project, I employed a multiple-case embedded design (Yin, 2009). I chose an embedded design because my research questions involved two

units of analysis, the classroom and the individual student. While all of the classrooms were located in one school, my research questions did not ask about the influence of the school as a whole. Thus the school served as the context, while the classroom was my unit of analysis and the individual student was a sub-unit of analysis. The multiple-case design allowed for cross-case comparisons at the classroom and student level. I collected data from multiple sources over the course of 7 months during one academic year, including (a) fieldnotes (Emerson, Fretz, & Shaw, 2011), (b) videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), (c) photographs and verbatim copies of literacy artifacts such as student work and teacher writing on the white board, (d) a survey completed by all students and (e) semi-structured interviews with a subsample of 12 focal students. In this thesis, I present the results of three studies that arose from my work at the Lyon Academy.

Study 1

The purpose of the first study was to document the standard literacy practices and text genres found in Ms. Marsh's four science classrooms (grades 6-8) at the Lyon Academy. The primary data source for this study was videorecorded classroom observations. I also triangulated the data using fieldnotes and photographs of literacy artifacts. Using quantitative and qualitative analysis techniques, I categorized the text genres used during reading and writing practices in Ms. Marsh's classrooms and described how these texts were used during classroom instruction. I also analyzed the similarities and differences between the "general-school" and "science-specific" literacy practices that happened in these classrooms.

Study 2

The purpose of the second study was to examine how Lyon Academy students' science identities are shaped by two primary factors: their teacher's language and instructional practices within their classrooms, and popular images of science from the world beyond their classrooms. The primary data sources for this study were fieldnotes, videorecorded classroom observations, and semi-structured interviews with the subsample of 12 focal students. Using qualitative analysis techniques, I first examined the teacher's language and instructional practices to determine what opportunities students were given to participate in the central practices of science and to build a science identity. I then explored what sources individual students drew on in constructing their own views of science. In particular, I was interested in understanding the ways in which two factors—language and instructional practices within the science classroom, and popular images and beliefs about science outside of the classroom—intersect to shape the Lyon Academy students' beliefs about science identity.

Study 3

The purpose of the third study was to explore the Lyon Academy students' attitudes toward science and constructions of science identity in more depth. The primary data sources for this study were survey results from all Lyon Academy students and interview data from three case study students. In addition, I triangulated the survey and interview data with data from fieldnotes and videorecorded classroom observations. Using quantitative and qualitative analysis techniques I first analyzed Lyon Academy students' responses relating to different aspects of science identity. I then explored the variation in their responses in more depth by discussing the experiences and beliefs reported by three case study students.

Conclusion

Taken together the findings from these three studies have several important implications for teachers, instructional leaders, and researchers interested in girls' science literacy and the persistent underrepresentation of women, and especially women of color, in science-related careers. First, the findings shed light on the kinds of text Lyon Academy students were reading and writing in their science classes (i.e., text genres) and what activities they were being asked to do with these texts (i.e., literacy practices). Such information is important to help teachers, instructional leaders, and researchers identify areas to focus on as more content area teachers are asked to meet the ambitious literacy goals contained in many college- and career-ready standards. Second, the findings revealed how Ms. Marsh's language and instructional practices positioned her students as working scientists and gave them access to values, activities, tools, and language that she indicated were central to doing science. These promising practices have implications for researchers interested in future studies of science instruction that helps underrepresented adolescents to take on disciplinary identities. Finally, the findings demonstrated the persistence of many limited and noninclusive views of who scientists are and what they do, even among girls attending an all-female school where their teacher actively encouraged them to view themselves as scientists and construct a more inclusive view of scientists. This suggests the need for science instruction that more actively promotes multiple visions of science that disrupt limited and noninclusive popular conceptions.

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Chapter 2: Study 1

Literacy Practices and Text Genres in Girls' Middle Grade Science Classrooms

Abstract

In the face of low adolescent literacy rates (NCES, 2012), concerns about the nation's prospects of remaining competitive in science and technology (Hill, Corbett, & St. Rose, 2010), a persistent gender gap in science (Hill, Corbett, & St. Rose, 2010; NCES, 2012; Reilly, 2012), and the continued rollout of the *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects* (CCSS; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), there is a need to focus on adolescent girls' science literacy. Such science literacy involves not only general knowledge about science, but also the ability to engage in the advanced reading and writing practices fundamental to doing science (Norris & Phillips, 2003). While it is clear that expert scientists use text before, during, and after the inquiry process (Yore et al., 2004), much less is known about the literacy practices and text genres used in science classrooms. The purpose of this article is to document the current literacy practices and text genres found in the four science classrooms (grades 6-8) of one science teacher at a small all-female school. Over the course of 7 months, I observed the regularly scheduled science classes on 1 to 2 days per week. During these observations, I collected in-depth data focused on reading and writing in these science classes from multiple sources, including (a) fieldnotes (Emerson, Fretz, & Shaw, 2011), (b) videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), and (c) photographs and verbatim copies of literacy artifacts such

as student work and teacher writing on the white board. Ten minute intervals from each observation were coded for literacy practices and text genres used. Findings indicate that students read and wrote a wide variety of genres, but were far more likely to read than write the type of sophisticated nonfiction privileged by the *Common Core Standards*. Moreover, over two-thirds of literacy practices were classified as “general school” practices rather than science-specific literacy practices. The majority of the science-specific literacy practices involved genres that were categorized as numbers and visual representations. These findings highlight the importance of genres beyond text to science instruction, while also suggesting that science teachers may need support in order to integrate text into their discipline-specific literacy teaching.

Introduction

It is time for Ms. Marsh's² 5th grade science class at the all-female Mary Lyon Academy for Girls (Lyon Academy). After brief instructions, Ms. Marsh gathers her fifteen students around a table at the back of the classroom to guide them in jointly constructing a chart displaying the results of a hands-on experiment testing the water tolerance of four different plant types. Ms. Marsh calls on Mandy who volunteers the vocabulary term “optimum condition” to describe the situation when a plant is “at its very best” and Ms. Marsh adds the phrase to a key she is creating below the chart. When she finishes, Ms. Marsh looks up and asks her students, “What’s missing?” She continues, “As scientists, we want to be specific, we want to use evidence, and we want to really communicate our thinking...Because, as scientists, it doesn’t matter what we find out unless we can share it with people.”

As this example illustrates, Ms. Marsh believes that specific ways of communicating—reading, writing, and speaking—are at the heart of her discipline. Her affirmation of the importance of communicating “as scientists” is significant in light of the college- and career-ready standards, such as the *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects* (CCSS; National Governors Association Center for Best Practices & Council of Chief State School Officers (NGA Centers & CCSSO), 2010), which renew the call for all educators across academic disciplines to take responsibility for their students’ literacy development. However, while standards such as the CCSS outline an ambitious vision of what it might mean to read and write according to disciplinary norms—“as scientists”—little is known about the current literacy practices found in classrooms like Ms. Marsh’s.

² all names are pseudonyms

In particular, there is a lack of knowledge about what kinds of texts students are reading and writing in their science classes (i.e., text genres) and what activities they are being asked to do with these texts (i.e., literacy practices). Although the term “genre” has been defined differently by different disciplines, here I use it to refer to conventional ways of organizing text for different purposes within the science classroom (e.g., lab report, diagram of a process). Such information about current literacy practices is important to help teachers, instructional leaders, and researchers identify areas to focus on as more content area teachers are asked to meet the ambitious literacy goals contained in many college- and career-ready standards.

As a first step in developing such knowledge, this article reports on the results of a case study of the literacy practices and text genres found in Ms. Marsh’s four middle grade science classrooms at the all-female Lyon Academy. Ms. Marsh is typical of many other skilled and caring content area teachers in that she has expressed interest in and concern with her students’ literacy development, but has no formal background or training in literacy. I, on the other hand, am a researcher concerned with adolescent literacy and a former teacher of reading to adults, but do not have Ms. Marsh’s expertise in science content. Like Ms. Marsh, I believe that specific ways of reading and writing are at the heart of every academic discipline. However, I believe that educators and researchers have yet to develop a common understanding of what it means to communicate in discipline-specific ways within content area classrooms. Thus my intention was that my collaboration with Ms. Marsh would draw on our collective knowledge and experiences to yield new insights into the current state of literacy in

science classrooms. Specifically, this exploratory study was guided by three research questions:

1. What are the text genres used in the reading and writing practices in the four science classrooms? How are the texts used in literacy practices?
2. What are the similarities and differences between science-specific and general school literacy practices that occurred in these classrooms?
3. Do the text genres and literacy practices vary across the classrooms that use different curricula (e.g., 5th and 6th grades vs. 7th and 8th grades)?

In the following sections, I review the background literature that has helped shape this study. I then present my findings and conclude with a discussion of these findings framed in the context of a rich vision of literacy in science classrooms.

Background Literature: Literacy in Science

Although the idea that all content area teachers are teachers of literacy is not new, earlier—and largely unsuccessful—incarnations of “content area literacy” emphasized general cognitive strategies thought to be applicable across disciplinary contexts (Shanahan & Shanahan, 2012). In contrast, many of the new college- and career-ready standards, such as the CCSS, reflect a belief in the importance of discipline-specific reading, writing, and language practices. According to this perspective, teaching discipline-specific literacy practices is not an add-on to the curriculum, but an integral part of helping students to acquire disciplinary knowledge. Relevant to Ms. Marsh’s classroom, this view is also expressed in the *Next Generation Science Standards*, which assert in *Appendix M: Connections to the Common Core State Standards for Literacy in Science and Technical Subjects*, “Literacy skills are critical to building knowledge in

science” (NGSS Lead States, 2013b, p.1). Of course, such statements raise the questions of which literacy skills (i.e., which literacy practices dealing with which text genres) are especially relevant to science and whether those discipline-specific literacy skills are present in science classrooms.

While the extant research does not fully address this question, in the sections that follow, I briefly discuss two relevant bodies of literature. First, I review a robust body of literature related to literacy among expert scientists. I then discuss the small body of literature that has attempted to shed light on the current state of literacy instruction in middle and high school science classrooms, ending by suggesting some important unanswered questions.

What Do We Know about Literacy Among Expert Scientists?

Drawing on years of research attending to language, semiotics, and science education, Lemke (2004) provided the following description of what an ethnographer studying literacy among working scientists might observe:

Backs of envelopes with incomplete sketches, isolated words, a few lines of mathematical symbols, some arrows and question marks. Meticulous notebooks full of dates, columns, headings, and numbers. Shelves of textbooks, treatises, and handbooks. Piles of offprints, pre-prints, re-prints, and print-outs. People talking while using a whiteboard like the back of an envelope. People entering numbers in notebooks while adjusting dials and tilting their heads at funny angles. People sitting silently at computer screens filled with numbers, graphs, and bizarre visual displays, making little notes on pads of paper. And once in a great while, someone sitting at a keyboard and creating complete sentences of

English, neatly arranged into paragraphs, and separated by lines of mathematical symbols or tables of numbers or graphs of crooked lines or diagrams of apparatus or more unusual visual displays (p. 33).

I would like to highlight three points illustrated by this description that have also received support in other literature.

First, literacy is an integral part of science, used throughout the inquiry process. In fact, Norris and Phillips (2003) argue that reading and writing should not be viewed as functional tools that can be used for doing science, but as necessary constitutive parts of science. In other words, science as currently practiced, could not exist without reading and writing (Norris & Phillips, 2003; Osborne, 2002).

Second, science requires multiple literacies. Full participation in science requires command of not only the narrow sense of text that literacy educators tend to focus on, but also the language of mathematics and multiple visual representations (Lemke, 2004). Scientific texts within and outside of the classroom routinely integrate a wide array of different elements including abstracts, section headings, figures, tables, diagrams, maps, drawings, photographs, reference lists and endnotes (Lee & Spratley, 2010). Experienced readers in science use structural elements such as headings to make strategic choices in their reading and recognize that many of the text elements present “alternative forms of overlapping information that has to be translated and compared” (Shanahan, Shanahan, & Misischia, 2011, p. 406).

Third, some of the text genres integral to science are used in the moment and can be produced quickly, such as an informal sketch briefly shown to a colleague, while others are complex extended pieces that require multiple revisions and are meant for a

broader and more removed audience, such as journal articles. It is the latter category that is highlighted by the CCSS, which emphasize reading and writing extended “sophisticated nonfiction” including texts that follow discipline-specific conventions for making arguments and providing information or explanations (NGA Center & CCSSO, 2010, p. 60). However, it may well be that reading and writing a wider array of genres is important in science classrooms both because they are integral to doing science and for pedagogical reasons as teachers scaffold their students’ construction of sophisticated nonfiction texts.

What Do We Know about Literacy in Science Classrooms?

A small body of literature describes typical reading and writing instruction in middle and high school content area classrooms. To my knowledge, five such studies, using diverse data collection methods and instruments such as observations, surveys, and interviews, include descriptions of the frequency of reading and writing activities or the genres found in science classrooms (Applebee & Langer, 2009, 2011; Fisher, 2009; Kiuahara et al., 2009; Lawrence, Phillips Galloway, Yim & Lin, 2014). An additional study of the instructional practices of science and mathematics teachers also sheds light on literacy instruction, although it was not an explicit focus of the study (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Of these six studies, four are concerned with writing in content area classrooms (Applebee & Langer, 2009, 2011; Kiuahara et al., 2009; Lawrence et al., 2014).

In general, these studies indicate that reading and writing instruction occurs infrequently in middle and high school science classrooms (Applebee & Langer, 2009, 2011; Fisher, 2009; Kiuahara et al., 2009). For example, Fisher (2009) observed three

“average” 10th grade students at a suburban school in all of their classrooms for 3 full days each. He classified the activities he observed into seven broad categories and documented the time spent on each. Across the 15 classrooms he observed, listening activities such as teacher lecture or watching a film accounted for the most instructional time (48%), while reading (6%) and writing (2%) accounted for the least. The writing-focused studies corroborate this low estimate of writing opportunities, especially related to extended text (Applebee & Langer, 2009, 2011; Kiuahara et al., 2009). For example, a nationally representative sample of science teachers estimated that during a 9-week grading period they ask students to write 3.5 assignments of a page or less, 1.5 assignments of one to two pages, and .5 assignments of three pages or more (Applebee & Langer, 2011).

Additionally, four studies shed light on the text genres students read and write in science classrooms (Applebee & Langer, 2011; Kiuahara et al., 2009; Lawrence et al., 2014; Weiss et al., 2003). While no study that I am aware of has systematically documented the types of texts read in science class, evidence suggests that textbooks predominate. For example, Weiss and colleagues (2003) conducted classroom observations and interviews with a nationally representative sample of science and mathematics teachers. When teachers were asked about what influenced the content of what they taught, textbooks were cited in almost half the lessons; only district and state standards were cited more frequently (Weiss et al., 2003). Textbooks also appear throughout the teachers’ discussions of their instructional choices (Weiss et al., 2003). Many students, and particularly the underrepresented students of focus in this study, are likely to experience difficulty comprehending these textbooks. In the first place, the

register employed is characterized by complex syntax, such as the use of embedded clauses, and specialized technical vocabulary, both of which differ in significant ways from everyday language (Lee & Spratley, 2010). Moreover, a substantial body of research has documented other challenging aspects of textbooks such as assumed background knowledge that students do not have, low-level cognitive questions within the text, problematic visual representations, and the underrepresentation of females and ethnic minorities in illustrations (For a review, see Kamil, 2010).

Turning to writing, a different picture emerges. In contrast to the complex informational texts students are asked to read, they are largely asked to write single words or short answers (Applebee & Langer, 2011; Kiuahara et al., 2009). For example, Applebee and Langer (2011) collected 8,542 writing assignments from the four core content area classes of 138 students attending schools with a reputation for excellent writing instruction. The majority of these assignments (81%) consisted of “fill in the blank and short answer exercises, and copying of information directly from the teacher’s presentation,” activities the authors described as “writing without composing” (p. 15). These findings are corroborated by teachers’ own reports of frequently assigned genres. Worksheets and short answer responses are the only genres that more than half of science teachers reported assigning once a week or more (Kiuahara et al., 2009). Finally, Lawrence and colleagues (2013) examined the genres found in the content area notebooks of a sample of students from one small school. They found six genres in the science notebooks, which I list in order of their frequency: written explanation (35.7%),

short answer (26.2%), notes from textbook or class (21.4%), computations (7.1%), journal (2.4%), and graphic representation (2.4%)³.

Taken together, these bodies of literature highlight several areas that have influenced the design and analysis of the present study. First, it is clear that the writing that happens in content area classrooms is better documented than reading. More information is needed on what, if any, text genres besides the course textbook students read. Second, Lemke's (2004) description of the literacy practices of a working scientist suggests that a text-centric framework might be too narrow to capture the full extent of what it means to be scientifically literate. This view is supported by Lawrence and colleagues' (2014) finding that computations and graphic representations accounted for almost 10% of the writing found in students' science notebooks. Third, studies of writing in science classrooms suggest that students are rarely asked to write extended text. Yet it is impossible to meet the challenge of college- and career-ready standards without doing this. Therefore there is a need to focus on what opportunities students are given to write sophisticated nonfiction texts. Finally, the disciplinary-literacy perspective highlights the need to teach discipline-specific reading and writing practices. Yet much of what is described in the extant literature appears to be general school literacy practices (e.g., filling in worksheet, copying notes, reading textbook independently) rather than practices specific to the discipline of science. This points to a need for more research into which, if any, literacy practices in science classrooms appear to be specific to "doing science" rather than "doing school."

Present Study

³ The remaining 4.8% of notebook entries were classified as "other."

My study began with the premise that Ms. Marsh and her students engage in particular literacy practices using texts of different genres in order to accomplish the work of “doing science.” While their local classroom practices might be influenced by some of the disciplinary practices found in the broader scientific community, they are not identical to them, in part because of the particular knowledge and beliefs brought by Ms. Marsh and her students and in part because of competing pressures found on the local level (e.g., pressure to achieve content coverage or teacher not viewing self as a disciplinary expert). While it is clear that expert scientists use printed text before, during, and after the inquiry process (Yore, Hand, & Florence, 2004), much less is known about the literacy practices and text genres used in science classrooms. This is especially true for those classrooms, like Ms. Marsh’s, that use a curriculum that privileges hands-on experiments. Thus the purpose of this article is to document the standard literacy practices and text genres found in Ms. Marsh’s four science classrooms.

Study Design and Methods

Study Design

The study employed a multiple-case design (Yin, 2009) with the classroom as the unit of analysis. While all of the classrooms were located in one school, the study did not ask about the influence of the school as a whole. Thus the school served as the context. Notably, because of the school’s arrangement, all four classes were taught by Ms. Marsh, the school’s lone science teacher. Thus, unlike in a comparison of classrooms with different teachers, any differences in science literacy practices cannot be attributed to differences in the teachers’ background, knowledge, or beliefs.

School Context: The Lyon Academy

The study was conducted at the Lyon Academy, a small nondenominational, non-profit, private school, located in an urban area in New England. The Lyon Academy was founded in 2000 to serve adolescent females, primarily girls of color from the city's working class households. The school's purpose was to offer girls facing economic hardship an "empowering educational program" focused on their intellectual and emotional growth during the formative years of early adolescence (grades 5-8). At the time of data collection, the Lyon Academy had a total enrollment of 55 students. Since the Lyon Academy is a small school, there is only one teacher for each content area, and students work with the same teacher over the course of 4 years.

Participants

Teacher. Ms. Marsh, the science teacher, is a white female with a Master of Arts in Teaching degree from an elite private university. At the time of data collection, she was 31 years old and in her 5th year teaching and her 4th year at the Lyon Academy. Because there was only one science teacher, the Lyon Academy used a two-year (A/B) curriculum cycle. The content taught changed between A and B years, but each year's 5th and 6th grade cohorts learned the same content. Similarly, the 7th and 8th grade cohorts shared science content. During the data collection year, 5th and 6th grade students studied Life Science with units on Environments, Microworlds, and Land and Water. The 7th and 8th grade students studied an Earth Science unit on Weather and Water and a Life Science Unit on Populations and Ecosystems. Unlike more traditional classrooms, instruction was not driven by a science textbook, although textbooks were present in the classrooms. Instead, the school purchased membership in a collaborative that gave them access to materials from several hands-on science curricula and students often engaged in

hands-on activities. During these activities, Ms. Marsh would typically demonstrate some or all of the procedures to the whole class while commenting on what students should do to complete the activity. Students would then complete the hands-on experiment, usually in pairs or small groups. Some hands-on activities lasted only a small portion of the science class, while others continued for several class periods or even weeks.

Students. I invited all 55 Lyon Academy students in grades 5-8 to participate in the classroom observation and survey portions of the study. Fifty students consented to participate. In Table 1, I present select demographic characteristics, by grade-level classroom. In all four classrooms, the majority of students were identified by school records as Latina, and Black/African American. Multiracial was the next most prevalent racial/ethnic designation. Only one participating student was identified as White and one as Asian (both 7th graders). While this information was not available by classroom, in the overall school, roughly half of students came from a home where a language other than English was spoken. In addition, in each classroom all or nearly all students were eligible for free or reduced price lunch. In spite of this economic need, for several years, Lyon Academy students had outscored their citywide peers on the New England Common Assessment Program (NECAP) test. Additionally, over 90% of Lyon Academy alumnae continued on to graduate from high school 4 years after leaving, and close to 100% did so within 5 years.

Data Collection

Over a 7-month period during a single academic year, I engaged in participant observation at the Lyon Academy for a full school day 1 to 2 days per week. The role of the researcher-as-observer can vary from complete participant to complete observer

(Creswell, 2009). My role best fits Creswell's (2009) classification of "observer as participant." My role of researcher was known to all students and school personnel and I remained largely silent, openly taking notes while science instruction was taking place. My goal was to be seen as a regular nonjudgmental presence in the classroom, there to learn from being attentive to classroom activities. While I acted primarily as an observer during academic instruction, I actively participated in other aspects of the daily life of the school. For example, Ms. Marsh and her students occasionally brought in snacks and I would eat and engage in informal conversations with the rest of the class. I also chatted informally with Lyon Academy students and teachers before or after class and in the halls and parking lot. In addition, I participated whenever there was an in-class "icebreaker" activity, such as sharing a piece of news from the weekend.

Each day I visited the Lyon Academy, I observed the regularly scheduled science classes (3-4 classes depending on the day of the week). I also observed Ms. Marsh's 5th grade morning advisory period and chatted informally with Ms. Marsh about what was happening in her classes before school and during lunchtime. I collected in-depth data focused on reading and writing in these science classes from multiple sources, including (a) fieldnotes (Emerson, Fretz, & Shaw, 2011), (b) videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), and (c) photographs and verbatim copies of literacy artifacts such as student work and teacher writing on the white board.

Data Analysis

Data collection and analysis were overlapping and iterative processes (Dyson & Genishi, 2005; Heath & Street, 2008). After classroom observations, I wrote memos to record emergent themes and use these themes to help guide what I attended to during

future observations. For example, early on I identified student notebook notes as an important genre in Ms. Marsh's classroom and began recording these texts verbatim in my fieldnotes. Toward the end of data collection, I began the data management strategy of transcribing 10-minute intervals from 30 minutes into each classroom observation. This detached selection of data for transcription was used to allow for attention to changes over time and mitigate against the selection of purely illustrative data that confirmed preconceived ideas (Heath & Street, 2008). My analysis of these transcriptions indicated that classes did not follow a strict daily routine (e.g., class always begins with taking notes, followed by hands on activity, followed by discussion) and thus the transcribed intervals present a fair representation of classroom activities. I confirmed this conclusion by consulting (a) the fieldnotes from all of my observations and (b) photographs and literacy artifacts to ensure that no frequently-occurring literacy activities were absent from the transcribed sample. Throughout data analysis, I engaged in a process of writing analytic memos, building theories, and returning to the data to verify, reject, and refine these theories.

Coding literacy practices. After data collection and transcription were complete, I coded all portions of observation transcripts that involved literacy in Atlas.ti qualitative analysis software. Because of the importance of multiple literacies to science, I defined literacy broadly to include visual and mathematical representations such as maps, equations, and diagrams. Next, I engaged in in-depth coding of the literacy-related portions of the transcriptions using an inductive open coding approach (Charmaz, 2006; Maxwell, 2005; Corbin & Strauss, 2008). My initial code list focused on type of literacy (e.g., reading or writing) and broad categories for what students were reading or writing

(e.g., internet, instructions). During the next round of coding I attended to Ms. Marsh's explicit messages about literacy and the purposes of the literacy practices. Finally, I coded literacy practices according to whether they were science-specific or general school literacy practices. Although the *content* of almost all texts was relevant to science, I considered a practice to be a general school literacy practice if the activity might be observed in classrooms from many other content areas. For example, I would consider students reading silently from a textbook to be a general school literacy practice, although I would consider an activity like analyzing the adequacy of an experimental design to be science-specific, even if the description of the design was presented in that same textbook.

Coding text genres. As a final step in my analysis I further refined the broad categories I had identified for what texts students were reading or writing by coding for text genre. In this process, I was guided by Biber and Conrad's (2009) definition of genres as language "varieties associated with particular situations of use and particular communicative purposes" (p. 21). From this theoretical perspective, communicative purpose rather than structure lies at the heart of genre:

Genres are not fixed structures that some great arbiter of writing and its forms has decreed long ago from on high, much as it might seem to student writers. Instead genres are living traditions—temporary flexible agreements about how to get communicative jobs done (Whitney, Ridgeman, & Masquelier, 2011, p. 526)

Thus, while I consulted other research that has attempted to define text genres found in classrooms (Hoffman, Sailors, Duffy, & Beretvas, 2004; Lawrence et al., 2014), I did not begin coding with a set list of possible genres. Instead, I was guided primarily by

considerations of the apparent communicative purpose of the text. For example, students in Ms. Marsh's classroom wrote several types of short connected text that I considered to be different genres when the apparent purpose changed (e.g., reporting facts you know *vs.* explaining a process). Finally, it should be noted that I considered written numbers and visual representations to be "texts" when they were the focus of literacy practices. For example, students in Ms. Marsh's classrooms frequently created data tables and charts. While these charts could theoretically be elements embedded in a longer text (e.g., laboratory report), in these classrooms, they served as stand-alone products. Therefore, I considered "Data Chart/Table" to be a text genre.

Findings

RQ1. What are the text genres used in the reading and writing practices in the four science classrooms? How are the texts used in literacy practices?

I identified 31 text genres used during 149 classroom literacy practices in the transcribed sample of observational data (Table 2). Of these genres, seven were classified as representing the type of sophisticated nonfiction favored by the CCSS (e.g., textbooks, science-related trade books, and serial publications). An additional ten genres consisted of numbers, such as mathematical computations, and visual representations, such as computer simulations and diagrams. Three genres were types of short science-related connected texts of several sentences to a paragraph, such as short explanations of processes. The remaining ten were "other" genres such as letters, assessments or worksheets.

Students in these four classrooms were far more likely to read than to write sophisticated nonfiction texts (Figure 1). In fact, these types of text appeared in over half

of classroom reading practices. The most commonly read genres of this type included textbooks (12%) and informational packets (12%), which Ms. Marsh often used as a means of delivering science content. Such texts were usually read by students independently or for homework. Although Ms. Marsh sometimes read (or had students read) aloud portions of these texts in class, they were rarely discussed other than to provide discrete facts or summary. Other sophisticated nonfiction texts that were present in the classrooms include science-related serial publications, experimental procedures, a science-related historical reference book, notebook notes, and trade books. It is also noteworthy that of the 31 text genres I identified, the greatest variety was used during classroom reading practices (Figure 2).

There was slightly less genre variety among the texts that Ms. Marsh's students wrote (Figure 3). Although the notes students copied from the white board into their notebooks were classified as sophisticated nonfiction, the content of the notes was generated by Ms. Marsh. Thus students did not have the opportunity to write any sophisticated nonfiction texts with self-generated content. Instead writing practices tended to focus on students writing numbers, computations or visual representations, which appeared in 38% of writing practices. The most frequently occurring genres of this broad type were experimental observations in which students sketched and wrote short observations of what they saw during a hands-on experiment (22%) and data charts or tables recording the results of such experiments (9%). After teacher modeling, students usually worked individually to produce the former and in small groups to produce the latter.

Finally, there was the least genre variety among literacy practices that involved both writing and reading equally (Figure 4). The genres used during these activities consisted almost entirely of genres falling into the “other” category including worksheets (57%), quizzes or tests (13%) and rubrics (13%). Not surprisingly, given these genres, most of the reading and writing literacy practices involved students writing words or short phrases independently or with a partner.

RQ2. What are the similarities and differences between science-specific and general school literacy practices that occurred in these classrooms?

Sixty-eight percent of the observed reading and writing practices were characterized as “general” school literacy practices, which might be found in any classroom regardless of content area. Examples of general school literacy practices that frequently occurred in Ms. Marsh’s classrooms include students independently reading texts, filling in worksheets, or copying notes from the board (Table 3). Many of these practices seemed to be driven by the goal of providing or reviewing science content, largely through independent reading or copying notebook notes, or by the goal of assessing students’ ability to reproduce the content through tests or worksheets. A typical example of a textbook reading activity in Ms. Marsh’s classroom follows:

- Ms. Marsh: OK. Last thing. Take out your green books. This is the last thing. So you’re gonna have thermometer article, twenty to twenty one. OK? And this is a new article but most of it’s review, and the new article is right after the thermometer article...
- Savannah: Do we have to read?
- Ms. Marsh: ... It’s called *Heating the Atmosphere*.

Savannah: We have to read that?

Ms. Marsh: Umm hmm.

Savannah: No wait.

Ms. Marsh: Now it's gonna be mostly review. There's a hot chocolate one and that gives you a little preview of what we're gonna do on Thursday, but they talk about radiant energy. They talk about conduction. They talk about how molecules, what happens when molecules absorb energy, so this is gonna help you study. This is review. (8th grade; 12/10/12)

As illustrated by this example, Ms. Marsh treated textbook readings as a way for students to independently acquire or review content knowledge. In addition, although a wide variety of text genres were used during these general school literacy practices (Figure 5), almost half (44%) of these practices used genres, like the textbooks found in the above example, that can be classified as sophisticated nonfiction. Thus during general school literacy practices, Ms. Marsh's students were often expected to independently extract content knowledge from these types of sophisticated texts.

The science-specific literacy practices found in Ms. Marsh's classrooms tended to be integrated with hands-on science activities. Examples of these practices include reading and carrying out experimental procedures, recording and sketching observations during hands-on experiments, and creating and interpreting diagrams, charts, and graphs. In contrast to the general school literacy practices, the science-specific practices used a narrower range of text genres (Figure 6) and the vast majority of these practices (81%) used genres that were classified as numbers and visual representations.

Although such conversations occurred infrequently, it was only during these science-specific literacy practices that Ms. Marsh explicitly addressed the norms of communicating in science. For example, she would bring up language norms such as using the metric system and precise technical vocabulary or thinking carefully about how to interpret the symbols present in diagrams. On another occasion she emphasized the norm of rereading experimental procedures to ensure accuracy in carrying them out, explicitly linking this strategy to being a good scientist:

We want to make sure to do it right. So, as a scientist, I'm going to go back to make sure. OK? I always go back and reread. It's a mark of a good reader. It's the mark of a good scientist. (5th grade; 3/21/13).

This was not the only occasion on which Ms. Marsh discussed rereading with her students. However, rereading was the only strategy for aiding text comprehension she explicitly mentioned during my observations.

RQ3. Do the text genres and literacy practices vary across the classrooms that use different curricula (e.g., 5th and 6th grades vs. 7th and 8th grades)?

In Table 4, I present a comparison of the text genres found in the classrooms that use different curricula. I observed a similar number of literacy practices in each group (73 practices in 5th and 6th grade classrooms vs. 76 practices in 7th and 8th grade classrooms). However, there were striking differences in the types of text genres and literacy practices across these groups.

First, sophisticated nonfiction texts were used more frequently in the higher grade-level classrooms. These types of texts were used in 38% of the literacy practices in the 7th and 8th grade classrooms, as compared to 27% of the literacy practices in 5th and

6th grade classrooms. Notably, this difference was driven by the more frequent presence of two text genres, notebook notes and the textbook. The 7th and 8th grade classrooms used notebook notes during 18% of their literacy practices, compared with 8% in 5th and 6th grade classrooms. Following a similar pattern, they used textbooks during 8% of their literacy practices, compared with 1% in 5th and 6th grade classrooms. As discussed in the overall findings, both of these text genres were used as a way for students to independently acquire or review content.

Second, although the two groups used genres focused on numbers and visual representations in a similar percentage of literacy practices (30% vs. 26%), there were striking differences in the genres present in the two groups. The literacy practices in the 7th and 8th grade classrooms often used genres associated with the language of mathematics, including computations, complex diagrams of scientific processes that involved computations, and chemical equations. In contrast, I never observed these genres used in the literacy practices of the 5th and 6th grade classrooms. Instead, in the 5th and 6th grade classrooms, the most common genre focused on numbers and visual representations was the experimental observation. During these literacy practices, students would observe an experiment, recording their observations with a sketch and short text. This genre was found in 18% of the 5th and 6th grade literacy practices, compared with 3% in 7th and 8th grade classrooms. These differences are noteworthy, because, as discussed in the overall findings, the majority of science-specific literacy practices in these classrooms used genres that were classified as numbers and visual representations. Thus, there were striking differences in the science-specific literacy practices across these classrooms.

Discussion

Low adolescent literacy rates (NCES, 2012), concerns about the nation's prospects of remaining competitive in science and technology (Hill, Corbett, & St. Rose, 2010), a persistent gender gap in science (Hill, Corbett, & St. Rose, 2010; NCES, 2012; Reilly, 2012), and the continued rollout of new college- and career-ready standards, all indicate a pressing need to focus on adolescent girls' science literacy. Yet little is known about the standard literacy practices found in middle and high school science classrooms, and especially those serving underrepresented groups. Thus this study was designed to document the standard literacy practices and text genres found in the four science classrooms of the Lyon Academy, a small all girls middle school serving primarily students of color and students from working class backgrounds. The findings I present in this article indicate that the teacher, Ms. Marsh, like many others concerned with adolescent literacy, is still grappling with how to identify and teach what it means to communicate "as a scientist." Such findings are not insignificant in light of previous unsuccessful attempts to promote "content area literacy" and the ambitious goals of college- and career-ready standards, such as the CCSS. In this section, I discuss four key findings from this exploratory study.

First, the study findings revealed a stark division between the types of texts that students read and those they wrote. The participating students were given far more opportunities to read than to write the types of sophisticated—and discipline-specific—nonfiction text genres described in the CCSS. While over half of the observed reading practices involved sophisticated nonfiction texts, only 26% of the writing practices did so (Figure 7). Moreover, the only sophisticated texts that students wrote were notebook

notes copied directly from the white board, an activity that fits Applebee and Langer's (2011) definition of "writing without composing." Across the academic year, I never observed the students being asked to compose their own sophisticated nonfiction texts. Unfortunately, previous research suggests that these classrooms are not unusual in giving students extremely limited opportunities to develop their writing abilities (Applebee & Langer, 2011; Kiuahara, Graham, & Hawken, 2009). However, this study extends previous research by documenting the reading and writing genres found in the same classroom, indicating that students may frequently be asked to read a variety of sophisticated nonfiction texts such as textbooks, serial publications, trade books and informational packets, while being asked to write mainly single words, phrases, or short connected texts. This finding is, perhaps, not surprising. Nonetheless, from a literacy perspective, it does indicate a missed opportunity to leverage the texts students read as models for what they write.

In addition, my analysis revealed a tension in the classrooms—a tension between general school literacy practices aimed at efficiently transmitting content to students and science-specific literacy practices, which captured some limited aspects of the disciplinary literacy ideal but occurred relatively infrequently and concentrated on a restricted number of text genres (Figure 8). For example, almost 70% of the literacy practices I observed were classified as general school literacy practices that might be found in any classroom. To an observer, these practices often look like students independently reading a text or filling out a worksheet. This finding suggests that the Lyon Academy classrooms are not unlike many other content area classrooms where students are expected to work independently to extract knowledge from sophisticated

nonfiction texts but are given little instruction relevant to the discipline-specific features of these texts that might impede their understanding (Lee & Spratley, 2010). In contrast, the science-specific literacy practices I observed focused largely on numerical and visual text genres, indicating the need for literacy researchers and educators to take seriously the contention that multiple literacies are crucial to the enterprise of science (Lemke, 2004). It also suggests that science content area teachers might be more comfortable providing instruction related to the aspects of oral and written language they see as most obviously particular to their discipline, such as numbers, symbols, technical vocabulary, and visual arrays. Given that one reason for the failure of content area literacy may be the generic nature of the recommendations for teaching literacy made to content-area teachers (Moje, 2008), identifying and building on such discipline-specific aspects of language may be particularly important to engaging science teachers in the challenging work that must be undertaken to meet the demands of the new standards.

Furthermore, in interpreting this finding related to the tension between general school and science-specific literacy practices, it is notable that the studied classrooms utilized curricula that promoted hands-on activities rather than more traditional textbook-based curricula. Given the *Next Generation Science Standards*' emphasis not just on science and engineering knowledge, but also on science and engineering practices (NGSS Lead States, 2013a), many science classrooms are likely to incorporate such hands-on activities. However, critics of such an approach have pointed out that it can lead to "hands-on, minds-off" science that is driven by the manipulation of materials to achieve the correct—and often easily guessed—end result rather than higher order thinking and active construction of conceptual knowledge (e.g., Roychoudhury, 1994). In fact,

pressure for teachers to cover content and for students to memorize large amounts of information can render hands-on activities add-ons to the main business of acquiring content through textbook reading and lecture (Roychoudhury, 1994; Trumbull, 1990).

Such pressures might be at least partially responsible for the division I observed between the more-frequent general school literacy practices, which did seem to be motivated by the goal of delivering or reviewing content, and the less-frequent science-specific literacy practices, which usually occurred in the context of hands-on activities. During such hands-on activities, I observed students recording numbers, writing brief observations of what they saw, and constructing graphs to display findings. However, I never observed them engaged in literacy practices that might promote higher order thinking such as gathering information relevant to their hands-on activity from multiple sources or explaining the results of their investigation in writing. Yet, if one takes seriously the idea that literacy is fundamental to doing science (Norris & Phillips, 2003), separating reading and writing from hands-on activities not only creates an artificial division, but also distorts students' understandings of the nature of science. While simply adding more reading and writing to hands-on activities would not automatically result in the hands-on and minds-on science envisioned by reformers (e.g., Duckworth, Easley, Hawkins, & Henriques, 1990), embedding relevant and carefully-selected literacy components into such activities does seem to have promise for actively engaging students in the types of reasoning and argumentation skills that lie at the heart of the discipline of science. For example, Concept-Oriented Reading Instruction (CORI) provides one research-supported example of what it might look like to have science instruction that

emphasizes literacy while simultaneously teaching science concepts and inquiry skills (Guthrie, Wigfield, & Klauda, 2012).

A third finding relates to differences in text genres and literacy practices across the two groups of students using different curricula. Specifically, the 7th and 8th grade students were more likely than the 5th and 6th grade students to read or write sophisticated nonfiction texts (Figure 9). This largely consisted of copying notes from the white board or reading from textbooks. This difference might be developmentally appropriate as these text genres will likely be important in the high school science classes the older students will soon attend. However, given the challenges such texts present to many adolescents (Lee & Spratley, 2010), it should not be assumed that a transition to their more frequent use for independent content acquisition or review is unproblematic and I saw little evidence that the 5th and 6th grade students were receiving instruction that might prepare them for this transition. In addition, the group comparison revealed differences in the text genres used during science-specific literacy practices. Namely, 7th and 8th grade students more frequently used genres involving the language of mathematics such as equations and computations, while 5th and 6th grade students more frequently sketched and took notes during experimental observations. These differences were most likely driven by curricular differences. Whereas the 7th and 8th grade students were studying Earth Sciences with a focus on chemistry and physics, the 5th and 6th grade students were studying Life Sciences with a focus on biology. It is, perhaps, not surprising to find some differences in text genres and literacy practices across groups of students that differ in both grade-level and curriculum used. However, these findings do caution against conceptualizing science-specific literacy practices in a static and

monolithic way. Instead, it may be more fruitful to consider the literacy practices especially relevant to different subfields of science as well as those that are more cross-cutting.

Finally, the study reveals the role of text genres beyond science textbooks in middle grade classrooms. Previous research has suggested that textbooks play a significant role in science classrooms (Weiss et al., 2003). However, there is little research attending to standard literacy practices in these classrooms and, to my knowledge, no study has systematically documented the text genres that students read in science. The present study reaffirms the idea that the science textbook, used during 12% of observed reading practices, is indeed a central genre. In fact, in the studied classrooms no other text genre was used more frequently and only informational packets appeared as often. Yet, it is significant that 20 other text genres were read in the same classrooms, indicating that success in Ms. Marsh's classrooms requires students to master a wide variety of text genres beyond the textbook. Overall, this finding suggests that research that focuses only on textbooks may misrepresent the reading demands present in science classrooms.

Limitations and Future Research

Although the scope of this study had advantages in that it allowed for the use of multiple in-depth coding schemes, it was a small-scale exploratory case study, and thus I would like to acknowledge several important limitations. First, the findings I present in this article are based on observations of science classes taught by a single teacher at one small school. It is unclear to what extent Ms. Marsh is typical of other science teachers in the middle grades and the small all-female Lyon Academy is certainly not typical of US

middle schools. Indeed, given the well-trained science teacher, small class sizes, and significant instructional time devoted to science, it is clear that this is not a worst-case scenario. All of these factors limit generalizability. Thus, while findings from this study raise intriguing questions, and several corroborate the existing research, there remains a need for large-scale research examining the literacy practices and text genres across a representative sample of science classrooms. In particular, this would help to answer the question raised by this article that focuses on the extent to which genres beyond the textbook play an important role in science classrooms. Next, because of the large amount of data I collected, I employed the data management strategy of transcribing only a portion of the videorecorded classroom observations. I consulted my fieldnotes from all observations, photographs, and literacy artifacts to ensure that no major literacy practices were omitted in the transcriptions. Still, I do not make the claim that this article contains an exhaustive list of all of the literacy practices and text genres found in Ms. Marsh's classrooms and it should not be interpreted as such. Next, I was not able to disentangle whether the differences I observed between the different classrooms were primarily due to developmental differences among the students or curricular differences. Future research should attend to this issue. Finally, this article does not contain Ms. Marsh's perspective on the instructional choices she made. Engaging teachers such as Ms. Marsh in conversations about their understandings of discipline-specific ways of communicating must be a part of any future research that seeks to help teachers like her to take up the challenge of the new standards and become teachers of the language and literacy practices that lie at the hearts of their disciplines.

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Table 1. Demographic characteristics of students, by grade-level classroom ($n=50$).

	Grade 5 ($n=12$)	Grade 6 ($n=17$)	Grade 7 ($n=14$)	Grade 8 ($n=7$)
Latina	75%	59%	57%	57%
Black	8%	35%	29%	29%
Multi-Racial	17%	6%	0%	14%
White	0%	0%	7%	0%
Asian	0%	0%	7%	0%
Eligible for Free or Reduced Price Lunch	92%	100%	93%	86%

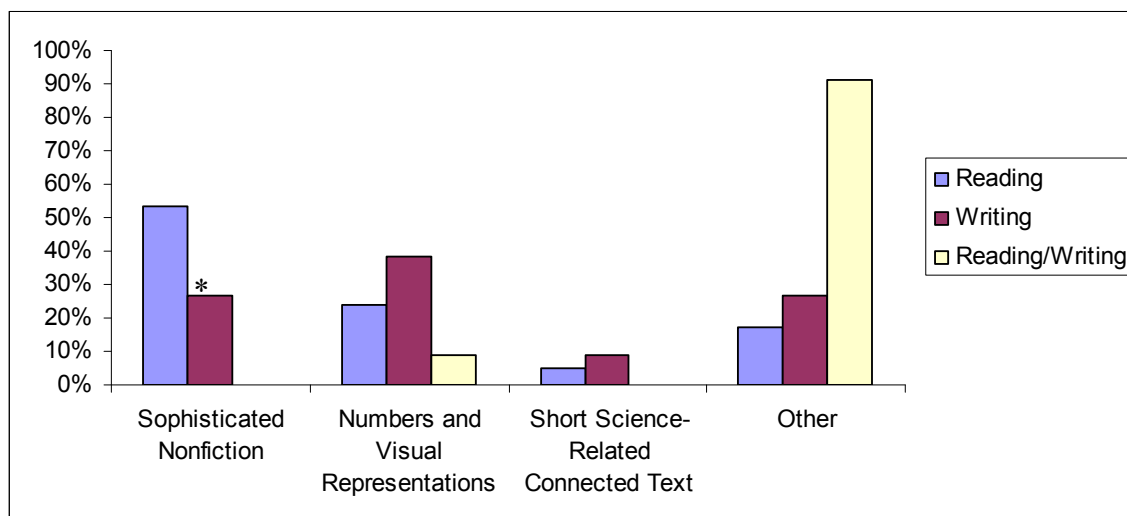
Table 2. Definitions and examples of text genres found in the science classrooms.

		Genre	Definition	Example from the Classrooms
Sophisticated Nonfiction		Experimental Procedures	Step-by-step instructions for what should be done to carry out a hands-on science experiment	Procedures for using wet mount and well slides to look at various objects under a microscope (5/6)
		Historical Reference Book	Book that has some historical significance in the field of science	Micrographia, a seventeenth century work by Robert Hooke recording his observations of objects using lenses (5/6)
		Informational Packet	Teacher-provided collection of short texts drawn from various sources	Packet of several readings explaining why the earth experiences seasons (7/8)
		Notebook Notes	Summary of information or concepts copied into student notebooks (sometimes also contain visual representation)	Notes generated by teacher and copied by students into their notebooks (all grades)
		Serial	Periodical such as a magazine or a newspaper	Serial magazine containing science news for a student audience (all grades)
		Textbook	Textbooks with a clear instructional design to be used in teaching science content	Textbooks (all grades)
		Trade Book	Books that are related to science content but do not have a clear instructional design	Informational books available in the classroom science library (all grades)
Numbers and Visual Representations		Annotation of Diagram	Numeric or text additions to a preexisting diagram	Temperatures added to a diagram showing how land and sea breezes form (7/8)
		Chemical Equation	Symbolic and numeric representation of a chemical reaction	Chemical equation for photosynthesis (7/8)
		Computation	Numeric notations with no extended text	Numbers entered into equation to solve for the density of an object (7/8)
		Computation and Diagram	Numeric notations that include a diagram as an integral part	Time of sunrise and sunset along with diagram used to calculate hours of sunlight in a day (7/8)
		Computer Simulation	Animated visual representation of a process on a computer	Online simulation of processes of convection and conduction (7/8)
		Data Chart/Table	Numeric notations arrayed in a table or represented graphically	Data chart showing the water tolerance of four seed types (5/6)

Short Connected Text	Diagram	Static visual representation of a process or concept	Visual representation of feeding cycle of secondary consumers (5/6)
	Editorial Cartoon	Illustration with some text in a serial publication containing commentary	Illustration commenting on the anniversary of the "Give a Hoot, Don't Pollute" campaign (7/8)
	Experimental Observation (Sketch and Short Text)	Notations of what students see during the course of an experiment containing text and visual representation	Short text descriptions and illustrations of what objects look like under a microscope (5/6)
	Map	Visual representation showing physical features of an area of land or water Short written text of a paragraph or less written in response to a teacher question about what students know (no claims or explanation)	Atlas map of Maine (5)
	Short Answer to Teacher Prompt		Student answers to question "What do you know about lenses so far?" (5/6)
	Short Explanation	Short written text explaining a concept or process	Short explanation of what happens on a molecular level when cold milk is poured into hot chocolate (7/8)
	Short Narrative	Short written text following narrative format Short text (usually a sentence or less) used to name or explain an object, photograph, or illustration	Short fictional story narrating events that resulted in a particular pattern of animal tracks in the snow (5)
	Caption/Label		Short explanations of what students were doing written below photographs of field trip to nature center (5/6)
	Game	Instructional material designed for student use (has to contain text and has to contain some element of a popular game, e.g., dice)	Game that involves rolling dice to see how a molecule of water travels through the water cycle (7/8)
	Homework Planner	Calendar in which students record their homework and important school events	List of texts to read and concepts to study for a text (all grades)
Other	Instructional Aid Chart	Visual aid or list compiling information used as part of instruction A written communication intended to be delivered to a recipient outside of the classroom	List of characteristics of a good caption provided by students and recorded by Ms. Marsh (5/6)
	Letter		Letters thanking chaparones for field trip to science museum and recounting what students learned (7/8)
	Poem and Illustration	Original poem with illustration	Cinquain poem and illustration (5/6)

Quiz/Test	Graded assessment of student learning taken in class	In-class quizzes or tests (all grades)
Rubric	Document that outlines expectations which students use to evaluate their own work or a work of a classmate	Rubric used to evaluate student notebooks at the end of each quarter (all grades)
Table of Contents	List of notebook entries for each quarter	List of notebook entries for each quarter (all grades)
Worksheet	Paper listing questions or tasks for students with space for short response	Worksheet where students fill in blank terms from a reading (all grades)

Figure 1. Comparison of broad text types used during reading practices ($n=58$), writing practices ($n=68$), and practices that involved reading and writing equally ($n=23$).



*Note: The only genre used during writing practices that fits into the broad type of sophisticated nonfiction is notebook notes. The content of these notes is generated by Ms. Marsh and copied verbatim by students into their notebooks.

Figure 2. Reading genres found in the four science classrooms as percentage of reading practices (n=58)

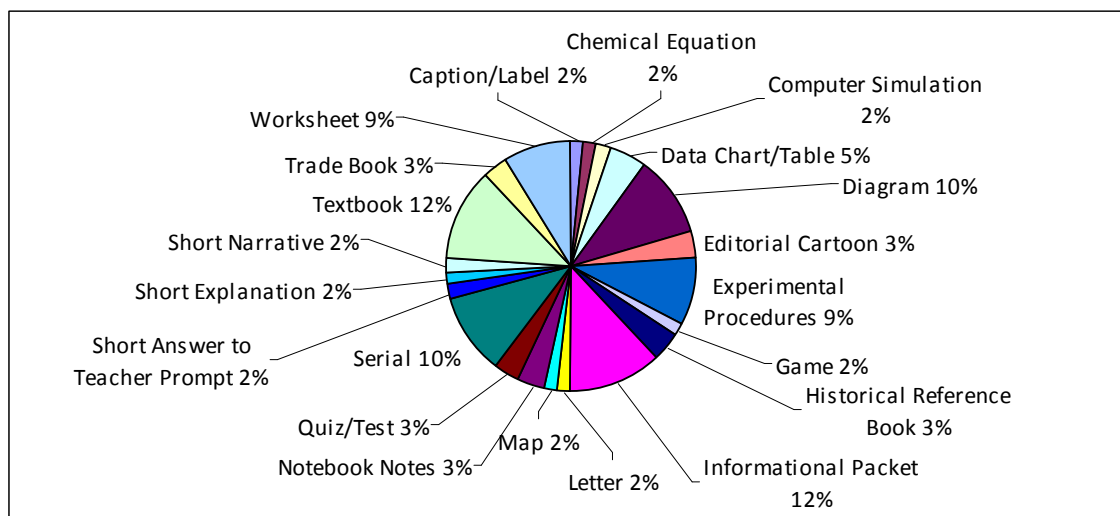


Figure 3. Writing genres found in the four science classrooms as percentage of writing practices (n=68).

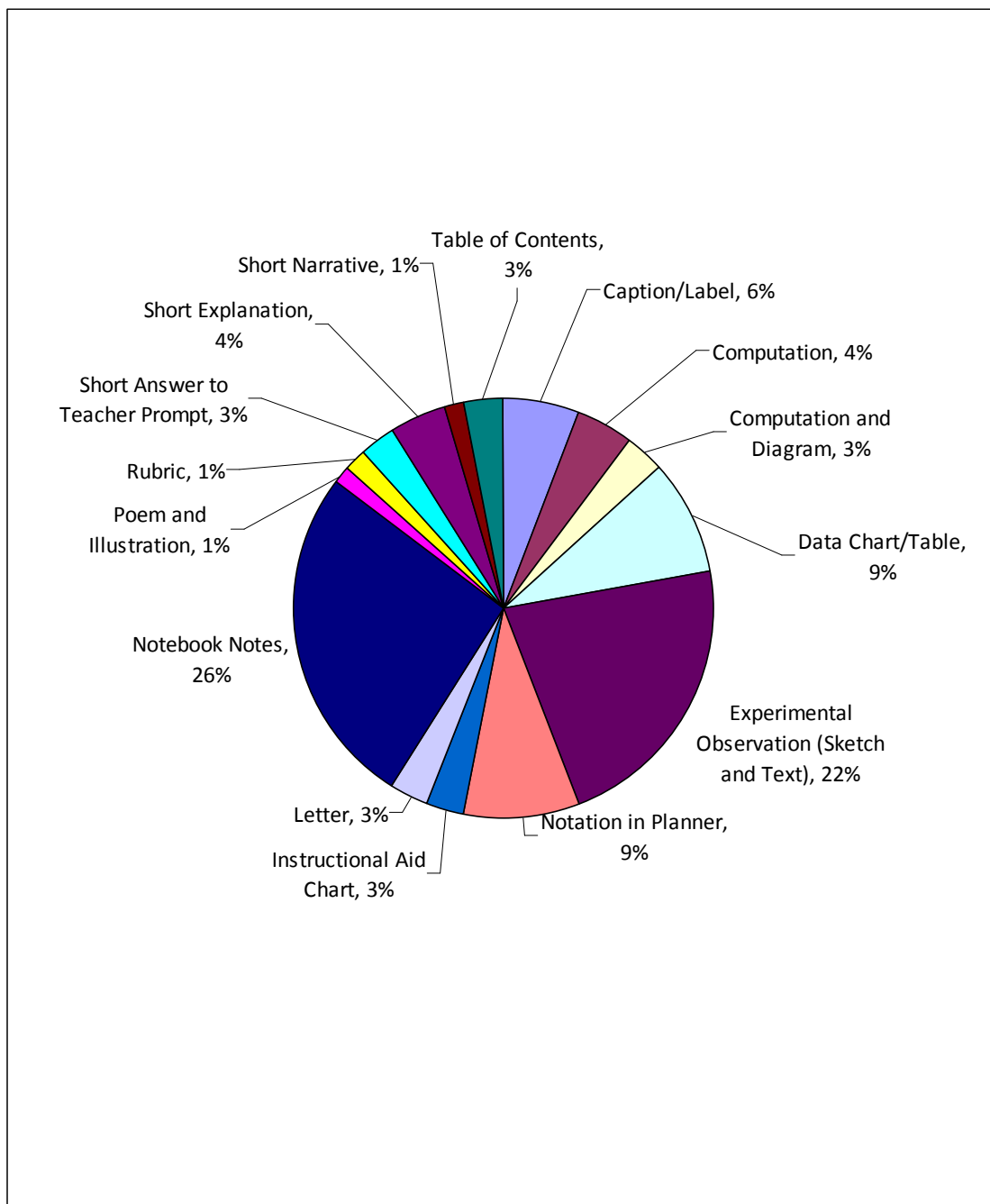


Figure 4. Reading/writing genres found in the four science classrooms as percentage of reading/writing practices (n=23)

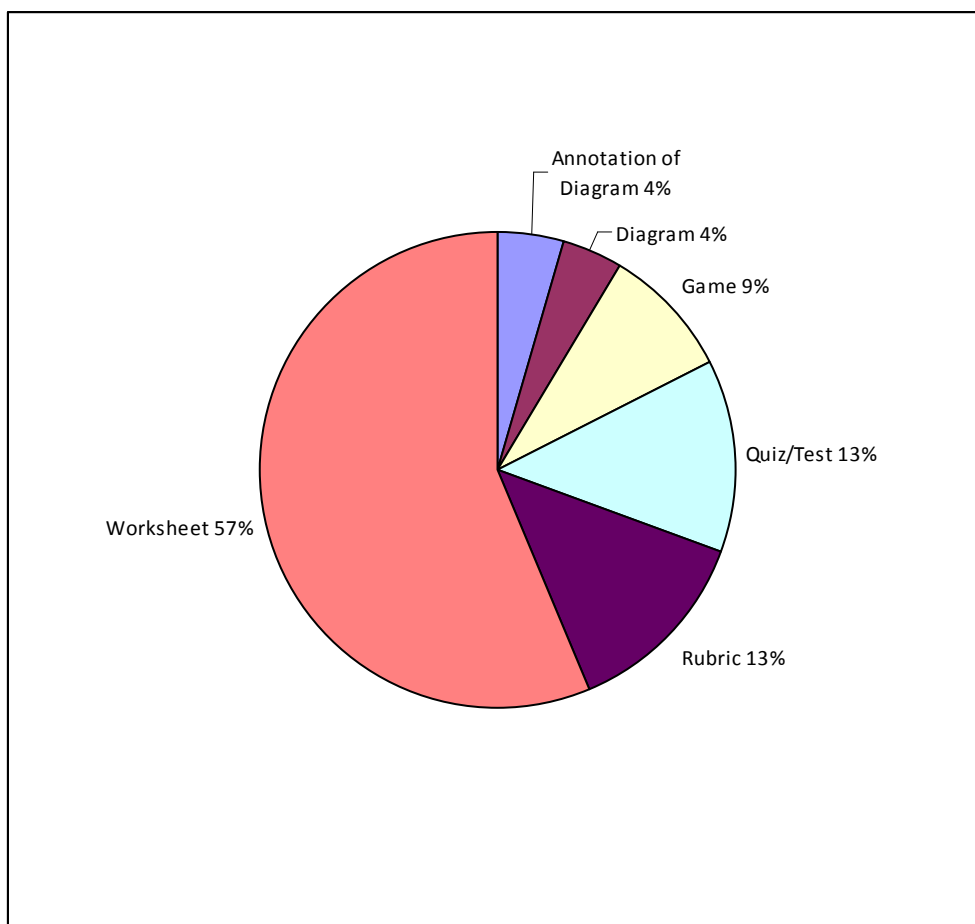


Table 3. Reading and writing practices that occurred commonly in the four science classrooms.

General School Practices	Science-Specific Practices
<i>Reading</i>	
<ul style="list-style-type: none"> • Read aloud written answers to questions • Read informational packets and textbook passages • Read science-related trade books and magazines • Report information learned from independent reading • Interpret environmental editorial cartoon • Read assessment directions 	<ul style="list-style-type: none"> • Discuss diagrams or computer simulations • Read and follow experimental procedures • Discuss data chart showing hands-on experiments results • Compare chemical equations
<i>Writing</i>	
<ul style="list-style-type: none"> • Copy notes from white board into notebooks • Write homework assignments in planner • Write short narrative or poem • Write labels and table of contents to organize notebook 	<ul style="list-style-type: none"> • Complete extended math problem • Construct data table, charts or graphs displaying hands-on experiment results • Write and sketch observations during hands-on science experiment • Create labels and captions for hands-on experiments • Write brief explanations of scientific processes
<i>Reading and Writing</i>	
<ul style="list-style-type: none"> • Fill in worksheets • Take quizzes/tests • Correct worksheets/quizzes/tests • Fill out rubric evaluating notebook 	

Figure 5. Text genres found in the four science classrooms as percentage of general school literacy practices ($n=102$).

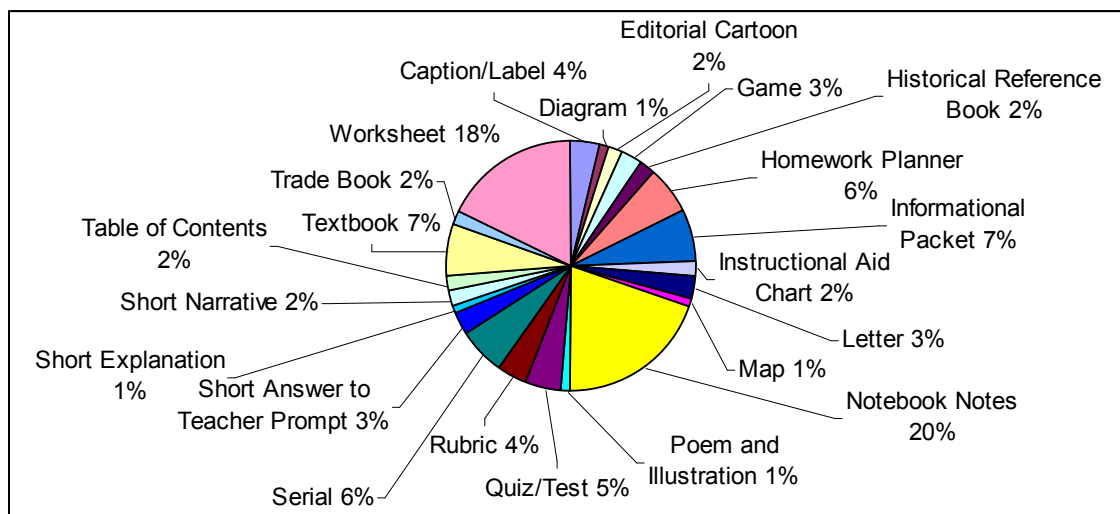


Figure 6. Text genres found in the four science classrooms as percentage of science-specific literacy practices ($n=47$).

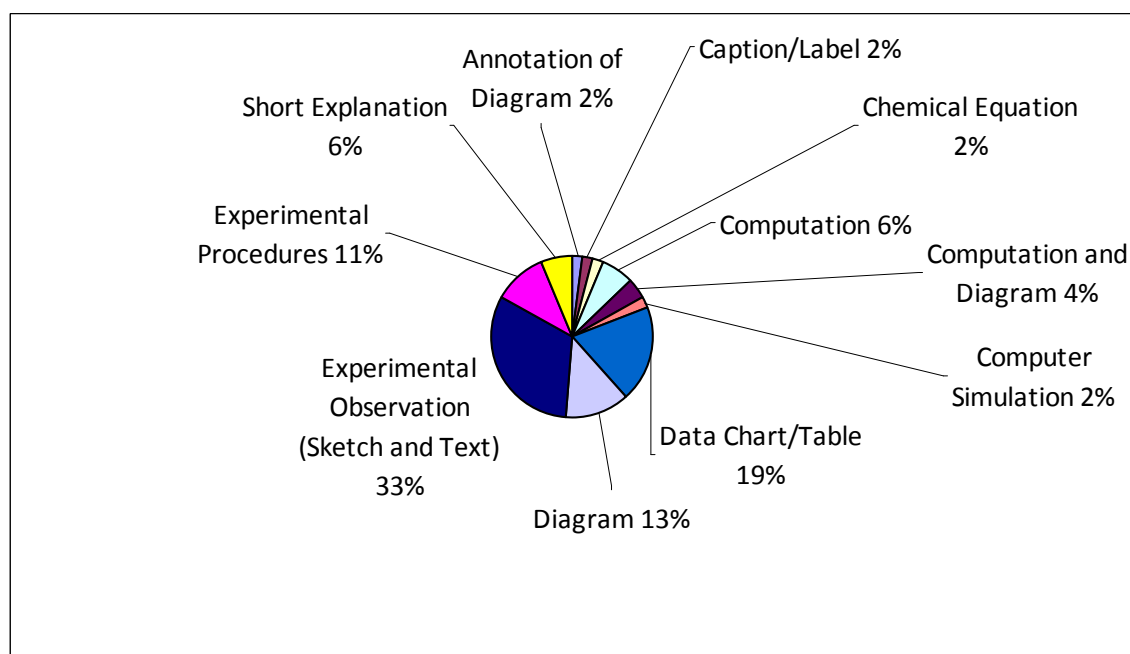


Table 4. Comparison of text genres found in the classrooms that used different curricula, as a percentage of literacy practices.

		5th/6th Grade Classrooms (<i>n</i> practices=73)	7th/8th Grade Classrooms (<i>n</i> practices=76)
Genre			
Sophisticated Nonfiction	Experimental Procedures	5	1
	Historical Reference Book	3	0
	Informational Packet	4	5
	Notebook Notes	8	18
	Serial	4	4
	Textbook	1	8
	Trade Book	1	1
	<i>Total</i>	27	38
Numbers and Visual Representations	Annotation of Diagram	0	1
	Chemical Equation	0	1
	Computation	0	4
	Computation and Diagram	0	3
	Computer Simulation	0	1
	Data Chart/Table	8	4
	Diagram	3	7
	Editorial Cartoon	0	3
	Experimental Observation (Sketch and Short Text)	18	3
	Map	1	0
	<i>Total</i>	30	26
Short Science- Related Connected Text	Short Answer to Teacher Prompt	3	1
	Short Explanation	1	4
	Short Narrative	3	0
	<i>Total</i>	7	5
Other	Caption/Label	5	1
	Game	0	4
	Homework Planner	5	3
	Instructional Aid Chart	1	1
	Letter	4	0
	Poem and Illustration	1	0
	Quiz/Test	0	7
	Rubric	5	0
	Table of Contents	1	1
	Worksheet	11	13
	<i>Total</i>	36	30

Figure 7. Comparison of broad text types found in the four science classrooms as percentage of reading practices ($n=58$) and writing practices ($n=68$).

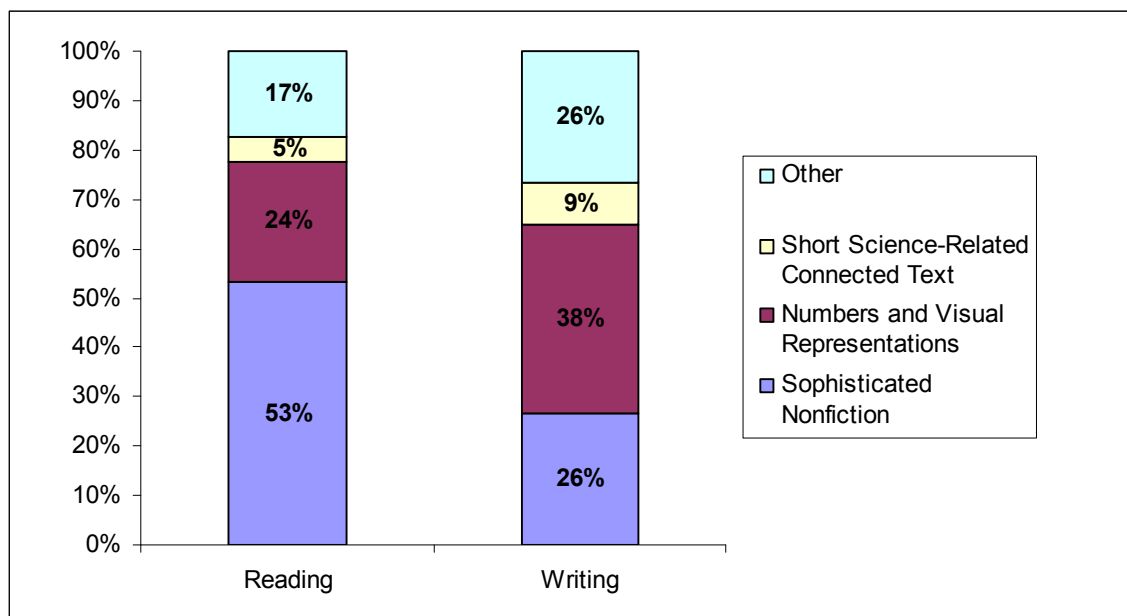


Figure 8. Comparison of broad text types found in the four science classrooms as percentage of general school literacy practices ($n=102$) and science-specific literacy practices ($n=47$).

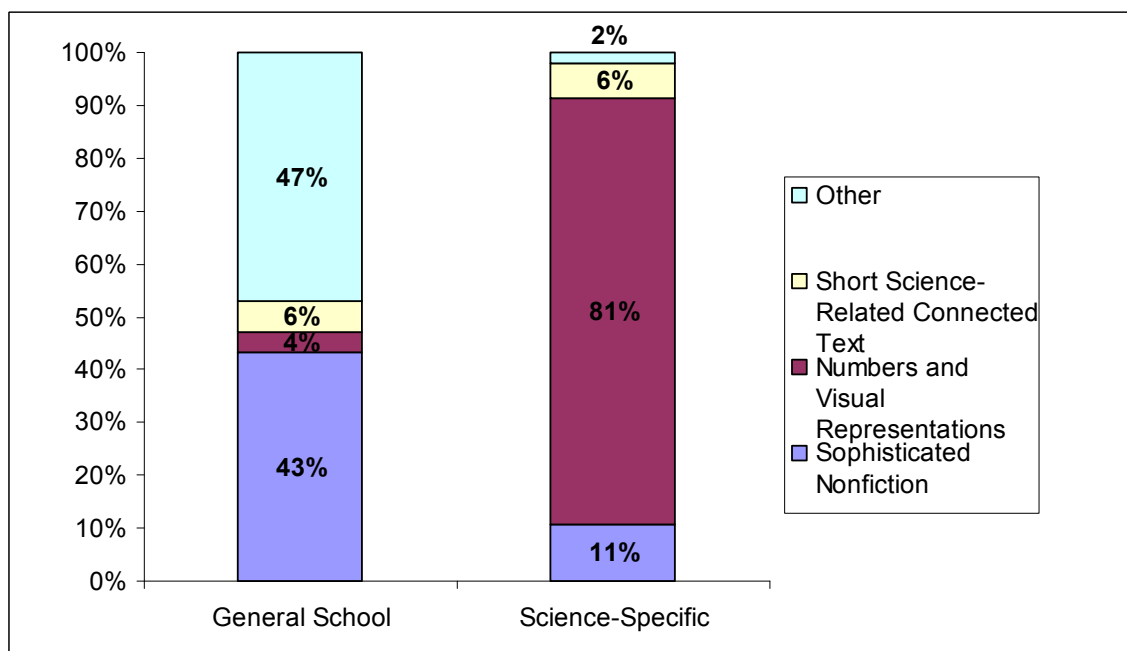
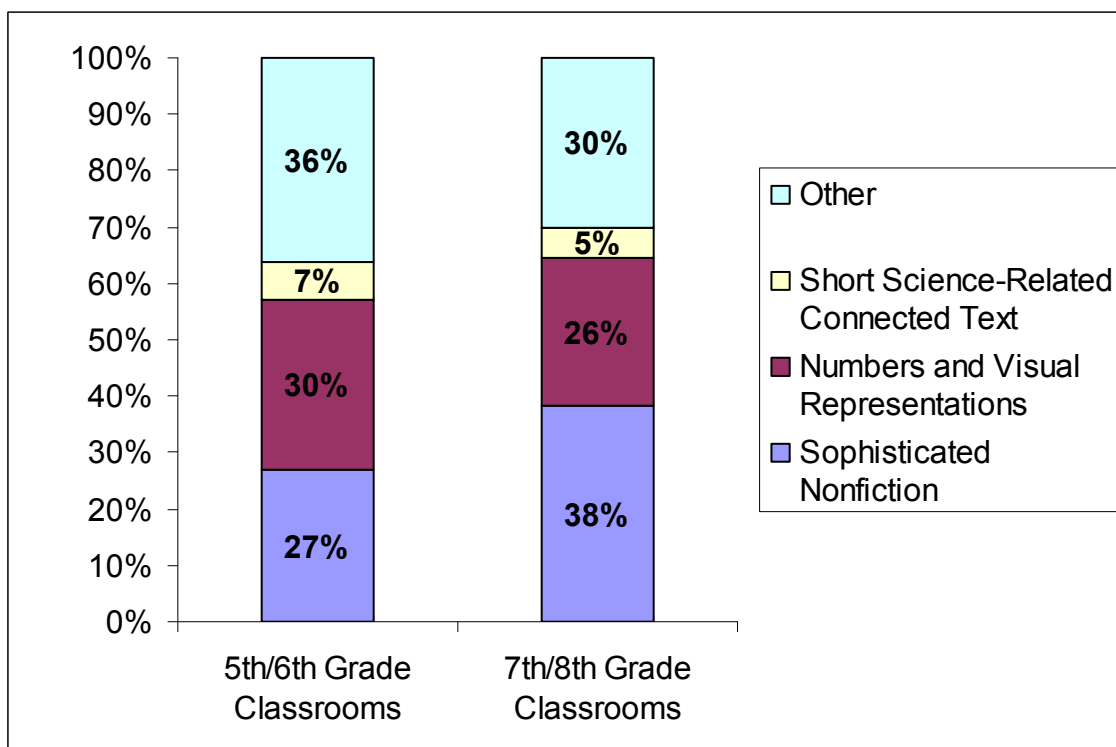


Figure 9. Comparison of broad text types found in the classrooms that used different curricula, as a percentage of literacy practices.



Chapter 3: Study 2

Shaping Girls' Science Identity:

Exploring the Role of Classroom Experiences and Popular Images

Abstract

Science identity—students' beliefs about who scientists are, what it means to do science, and whether science is interesting or important—is increasingly receiving attention as a possible explanatory factor in the persistent underrepresentation of certain groups in science. Therefore, the purpose of this paper is to examine how a teacher's language and instructional practices within her classrooms, and popular images of science from the world beyond their classrooms might shape adolescent girls' science identities. The multiple-case embedded study was conducted over the course of 7 months in 4 science classrooms (grades 5-8; 50 students) taught by a single teacher in a small all-female middle school. I collected in-depth data focused on science identity from multiple sources, including fieldnotes (Emerson, Fretz & Shaw, 2011), videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), and semi-structured interviews with a subsample of 12 focal students (ranging from 18 to 37 minutes). My research was guided by the following questions: (a) Do the teacher's language and instructional practices give her students opportunities to view themselves as scientists doing science? (b) Do the teacher's language and instructional practices make science relevant to her students' daily lives? (c) Do individual students draw on or contest the science identities made available in their science classrooms? (d) Do individual students draw on or contest the science identities presented in popular images of science? (e) Do

individual students talk about science as relevant, interesting, and open to people like them? Findings indicate that, within her classroom, the teacher clearly positioned her students as working scientists and gave them access to values, activities, tools, and language that she indicated were central to doing science. Moreover, the teacher's language and instructional practices served as important resources for her students to draw on in constructing their own views of who scientists are and what it means to engage in science. However, in addition to drawing on this more inclusive view, students' beliefs about science were also influenced by more limited archetypal images of scientists found outside of their classrooms (e.g., scientist as White male in lab coat). Taken together these findings highlight the dynamic and complex nature of identity formation.

Introduction

In spite of progress over the past forty years, American females continue to score lower than their male counterparts on tests of science achievement and pursue science-related careers at lower rates (Hill, Corbett, & St. Rose, 2010; NCES, 2012; Reilly, 2012). Girls' science identity—that is, beliefs about who scientists are, what it means to do science, and whether science is interesting or relevant—may be an important lens for understanding these persistent differences (Archer et al., 2012; Wong, 2012). In this article, I report on a multiple-case embedded study of science identity that I conducted over the course of 7 months in four science classrooms (grades 5 through 8; 50 students) taught by a single teacher in a small all-female middle school. I first examined the teacher's language and instructional practices to determine what opportunities students were given to participate in the central practices of science and to build identities as the “kind of” people who do science. I used the following two questions to guide this aspect of my research: (a) Do the teacher's language and instructional practices give her students opportunities to view themselves as scientists doing science? (b) Do the teacher's language and instructional practices make science relevant to her students' daily lives? I then explored what sources individual students drew on in constructing their own views of science. In particular, I was interested in understanding the ways in which two factors—language and instructional practices within the science classroom, and popular images and beliefs about science outside of the classroom—intersect to shape adolescent females' beliefs about science identity. I used an additional three questions to guide this aspect of my research: (a) Do individual students draw on or contest the science identities made available in their science classrooms? (b) Do individual students draw on or contest

the science identities presented in popular images of science? (c) Do individual students talk about science as relevant, interesting, and open to people like them?

Theoretical Framework

In an era where policymakers often link the future health of the economy to the preparation of leaders in the fields of science, technology, engineering, and mathematics (STEM; Hill, Corbett, & St. Rose, 2010), persistent gender differences in science are cause for concern. While female high school students now earn math and science credits at the same rate as males and receive slightly higher grades in these courses (NCES, 2007), gender differences favoring males persist in standardized tests of science achievement (NCES, 2012; Reilly, 2012), attitudes toward science (Archer et al., 2012; Archer et al., 2010), and representation among those pursuing STEM degrees and careers (Hill, Corbett, & St. Rose, 2010). Taken together, these findings indicate that, even with similar patterns of access, social and cultural mechanisms continue to influence females' views of science and whether or not they pursue STEM fields beyond high school. Through the lens of identity, the present study explores these mechanisms in the middle grades, when students transition from learning science in self contained elementary classrooms to learning science in a content area classrooms—a transition that is often associated with a decline in science motivation (Archer et al., 2010).

The study draws on Gee's (2001) dynamic definition of identity as "being recognized as a certain 'kind of person,' in a given context" (p. 99), which is broad enough to include both self-recognition as having a particular identity and recognition by others. In order to recognize themselves as having a science identity, students must be willing and able to engage with the language and conventional practices of science,

including accepting tradeoffs that occur when there is a conflict between scientific and everyday ways of knowing and communicating (Gee, 2004). For example, in contrast to everyday language, scientific language is characterized by abstract rather than concrete subjects and a detached stance (Gee, 2004). Accepting such tradeoffs makes sense only if one sees a benefit to being able to construct knowledge and communicate in scientific ways. Thus, inherent in science identity is the belief that science is relevant, interesting, or useful in some respect. Additionally, it requires a belief that neither external barriers nor internal capabilities limit the student's ability to engage with science. In other words, whether or not students view science as being for people "like them" appears to be an important factor that influences their identity formation (Archer et al., 2012; Archer et al., 2013; Wong, 2012). Thus, for the purposes of this study, I treated language and instructional practices that indicated who scientists are (and are not) and what it means to do science as aspects of science identity. I also considered whether the teacher and students framed what they did in the classroom as being science and whether they depicted science as relevant beyond the classroom.

Building Identities within Classroom Communities

One productive way to think about the relationship between what happens in a classroom and the development of identities is to consider the classroom as a community of practice. A community of practice can be defined as a group of people who care about a particular domain of knowledge and, through social interaction, develop a shared set of "practices"—activities, tools, language, etc.—that help the group accomplish something (Wenger, McDermott & Snyder, 2002). As "people who care" about a particular domain, members of a community of practice necessarily share a certain identity, but the strength

of this identity may differ among “newcomers” and “old-timers.” Newcomers to the community strengthen their identities through participation in the community when they are given legitimate access to the community’s central practices and tools (Lave & Wenger, 1991). Access to the tools specific to a community may be particularly important for increasing newcomers’ knowledge and sense of belonging to the community. For example, Marshall (1972) documented how denying apprentice butchers access to the tools and related practices central to cutting meat in favor of less central training tasks (e.g., wrapping meat cut by someone else) kept the apprentices from fully identifying with and understanding their chosen trade (as cited in Lave & Wenger, 1991). In the case of classrooms, students can be thought of as the newcomers to the community and teachers as the more experienced old-timers. Thus, in considering students’ science identity formation, it is important to examine what opportunities teachers give their students to participate in practices central to doing science, including using the tools of science.

Previous research in science classrooms has identified ways in which teachers’ language and instructional practices within classroom communities can promote or hinder students’ abilities to see themselves as the “kind of people” who do science. For example, teachers often use linguistic markers, such as personal pronouns that identify themselves and their students as members of scientific communities (Goldberg, Welsh & Enyedy, 2008; Moje, 1995). As reported in a study of teacher talk in a high school chemistry class, when a student indicated that the term “actual yield” might be “what the chemists get,” her teacher responded by including the student in the scientific community, saying, “Yes. It’s what *you* get. You’re a chemist, too. You’ll get an actual yield in the lab”

(Moje, 1995, p. 364). Even when teachers are not directly referencing science identities, the language and practices in science classrooms promote particular views of who can engage in science. For example, Lemke (1990) describes how both the conventions of science texts used in classrooms and teachers' attitudes toward science can promote what he calls "a harmful mystique of science," the belief that science is inherently too complex to be understood by anyone outside of a "superintelligent elite" and thus out of reach for most students (p. 160). In the particular case of female students, viewing themselves as the "kind of person" who does science can be hindered when teachers implement whole group discussion practices that favor males, elaborate more on the contributions of male students, or implement mixed-gender small groups that males dominate while females take on more passive roles. (For a review of this research, see Guzzetti, 2004.)

Encountering Popular Images

Of course, students are neither blank slates nor passive recipients of their teachers' views on who scientists are and what it means to do science. Even before they enter science classrooms, students encounter popular images of science and scientists which influence their beliefs about science as a discipline and who can participate in it. For example, studies spanning three decades have demonstrated that, although more inclusive images are possible, among students the enduring archetypal image of a scientist remains a lone White male with a labcoat, glasses, and facial hair, holding laboratory equipment (Barman, 1997; Chambers, 1983; Reveles, 2009). More recently, Archer and colleagues (2013) demonstrated that popular constructions of careers in science as "brainy," "not nurturing," and "geeky" are common among British girls as early as primary school and are also often shared by their parents. Such popular images

and beliefs about science can interact with other aspects of identity—such as gender, social class, and ethnicity—to influence whether girls, and especially those from working class and ethnic-minority backgrounds, believe that science is for “people like me,” and whether they choose to pursue it as a career (Archer et al., 2013; Wong, 2012).

Linking Classroom Experiences and Student Identity

Much of the research reviewed above has focused on one unit of analysis, either the classroom (e.g., Goldberg, Welsh & Enyedy, 2008; Lemke, 1990) or the individual student (e.g., Archer et al., 2013; Barman, 1997; Chambers, 1983; Wong, 2012).

However, a few, largely ethnographic, studies have attempted to link teachers’ language and instructional practices with student experiences and identities. In this section, I briefly review this research, and close by suggesting a number of remaining questions for the field.

First, Moje’s (1995) analysis of lesson transcripts and interviews from an ethnographic study conducted in a high school chemistry class demonstrated the ways in which the teacher’s language promoted students’ identification with science. She found three patterns in the teachers’ talk: (a) it reinforced the idea that science is “a discipline that required organization, accuracy, and precision,” (p. 355), (b) it presented science as unique and distinct from other disciplines, and (c) it included personal pronouns that identified both the teacher and the students with the science community. Her analysis of interviews with three students in this classroom indicated that the teacher’s talk did, in fact, encourage students to develop particular views of science, foster disciplinary identity, and build classroom community, although it also encouraged students to defer to

the expertise of the teacher or textbook. Notably, this study was conducted at a school where both the students and teaching staff were predominately White and middle class.

More recently, Carlone and colleagues (Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Carlone, Scott, & Lowder, 2014) have engaged in a program of ethnographic research that examines students' participation in and identification with school science, especially among groups often underrepresented in science, such as girls and ethnic minority students. In one study Carlone (2003) analyzed lesson transcripts and interviews and found that the teacher's language and instructional practices when using a reform-based physics curriculum in a primarily White upper middle class high school promoted two ideas: (a) science as requiring active participation and problem solving and (b) science as difficult and hierarchical. Moreover, she found that the girls taking this course were primarily concerned with being seen as "good students" rather than engaging in science in a meaningful way and resisted aspects of the curriculum that might threaten their "good student" identities. A second study compared teacher language and instructional practices in two ethnically and economically diverse reform-based fourth grade science classrooms (Carlone, Haun-Frank, & Webb, 2011). While students in both classrooms developed similar levels of understanding of science and expressed positive attitudes about science, in one of the classrooms a group of African-American and Latina girls expressed disaffiliation with "science people." The researchers attributed this disaffiliation to the differences in classroom practices: in the classroom where they observed disaffiliation, students individually took turns with trying out ideas and tools in order to get the right answer (and prove to the teacher that they knew the right answer), while in the other classroom students engaged in more collaborative investigations in

which different students' observations and questions were used to move the groups' work forward. The final study followed three students, one Latino boy, one White girl, and one African-American girl, during their 4th- and 6th-grade years to examine their science classrooms as related to the students' "identity work" (Carlone, Scott, & Lowder, 2014). In this study, Carlone and colleagues (2014) found that moving from a 4th-grade classroom where being a "smart science student" involved critical thinking, persistence, and nurturing peers to a 6th-grade science classroom where it involved memorizing and compliance led some students to engage in less scientific (but more compliant) behaviors or to disaffiliate with school science entirely.

Taken together, there is a growing body of research that indicates that science identity might be an important factor in explaining young people's science engagement and achievement. Moreover, factors both within and beyond science classrooms appear to influence young people's science identity formation. However, there are several important areas in need of investigation. First, little is known about how adolescents in different classroom contexts are socialized into different views of science. Specifically, although it is not uncommon that proposals to address the underrepresentation of women in science call for single-gender science classrooms, there is very little empirical work investigating how students in such settings construct science identity. Second, although classroom experiences and popular culture both appear to play an important role in shaping young people's views of what it means to be the kind of person who does science, very little empirical work has examined both of these factors together. Finally, very few of the classroom studies that link classroom experiences to student constructions of science identity have focused on racial/ethnic minority students, students from

working class families, or students who speak English as a second language. Since these same groups are often underrepresented in the field of science, there is a need for more research that considers their perspectives. To begin addressing these needs, in the present article I report on the results of a multiple-embedded case study of science identity conducted in one small all-female school serving primarily students of color from working class homes.

Study Design and Methods

Study Design

The study employed a multiple-case embedded design (Yin, 2009), which allowed cross-case comparisons at the classroom and student levels. The embedded design was chosen because my research goals involved two units of analysis: the classroom and the individual student. At the classroom level, I wanted to better understand the ways in which the teacher's language and instructional practices gave her students opportunities to view themselves as scientists, engage in central practices of science, and view science as relevant, or, conversely, the ways in which they denied students these opportunities. At the student level, I was primarily concerned with what sources individual students drew from in constructing (or rejecting) science identities, as well as how interesting and/or relevant the students said science was to them. While all of the classrooms were located in one school, the study did not ask about the influence of the school as a whole. Thus the school served as the context, while the classroom was the unit of analysis and the individual student was a sub-unit of analysis.

Study Context

The case study was conducted at the Mary Lyon Academy for Girls (Lyon Academy)⁴, a small nondenominational, non-profit, private school serving adolescent girls in grades 5-8. Located in a mid-sized city in New England, the Head of School described the Lyon Academy as designed to provide a “gender-specific, holistic educational experience.” The school was founded in 2000 and, at the time of data collection, had an enrollment of 55 students. Because of the Lyon Academy’s small size, there was only one teacher for each content area, and students worked with the same teacher over the course of 4 years. For several years, students at the Lyon Academy outscored their citywide peers on the New England Common Assessment Program (NECAP) test. Additionally, over 90% of Lyon Academy alumnae continued on to graduate from high school 4 years after leaving, and close to 100% did so within 5 years.

Participants

Teacher. Ms. Marsh, the science teacher, is a White female with a Master of Arts in Teaching degree from an elite private university. At the time of data collection, she was 31 years old and in her 5th year teaching and her 4th year at the Lyon Academy. Prior to becoming a teacher, she worked for several years in afterschool programs in the same urban area in which the Lyon Academy is located. Unlike more traditional classrooms, instruction was not driven by a science textbook, although Ms. Marsh sometimes assigned short readings drawn from several textbooks, as well as science-related tradebooks and magazines. Thus, in addition to more traditional activities, such as reading science texts, teacher-directed interactive lectures, and copying notes from the board, Ms. Marsh often structured science activities so that her students engaged in hands-on experiments, usually in pairs or small groups. In these instances, Ms. Marsh

⁴ All names of people and places are pseudonyms.

would typically demonstrate some or all of the procedures to the whole class while commenting on what students should do before sending them off to try the experiment. Some of these experiments were quick, lasting only a small portion of the science class, while others stretched out over the course of several class periods or even weeks.

Students. I invited all 55 Lyon Academy students in grades 5-8 to participate in the classroom observation portion of the study. Fifty students consented to participate. According to school records, 62% of these students were Latina, 26% Black, 8% multiracial, 2% Asian and 2% White. Roughly half of these students came from a home where a language other than English is spoken and 94% were eligible for free or reduced-price lunch. In addition, a subsample of 12 focal students also participated in interviews. For each grade, I interviewed one student the teacher identified as average in science achievement, one student she identified as below average, and one student she identified as above average. In Table 1, I present demographic information for this subsample.

Data Collection

Data were collected over a 7-month period during a single academic year. During this period, I typically visited the Lyon Academy for a full school day 1 to 2 times per week, observing the regularly scheduled science classes, as well as the 5th grade advisory period, which Ms. Marsh led. In addition, I often chatted informally with Ms. Marsh about what was happening in her classes before school or during lunchtime. I collected in-depth data focused on science identity from multiple sources, including (a) fieldnotes (Emerson, Fretz & Shaw, 2011), (b) videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days), and (c) semi-structured interviews with the subsample of 12 focal students (ranging from 18 to 37 minutes). While the student interview

protocol included questions related to many aspects of science literacy, analysis for this study focuses on the questions most relevant to understanding the students' constructions of science identity (See Appendix). Thus my analysis concentrates on the portions of the interview where students talked about (a) how they felt about science, including whether they liked it and whether they ever used things they learned in science class outside of school, (b) an imagined scientist at work, (c) an image of themselves in science class, and (d) whether 13 images I showed them were related to science or not, and how they knew this.

Researcher Stance

The role of the researcher-as-observer can vary from complete participant to complete observer (Creswell, 2009). My role best fits Creswell's (2009) classification of "observer as participant." All students and school personnel knew that I was a researcher. During science instruction, I remained largely silent, openly taking notes. While I acted primarily as an observer during academic instruction, I actively participated in other aspects of the daily life of the school. For example, Ms. Marsh and her students occasionally brought in snacks and during those times I would eat and engage in informal conversations. I also chatted informally with Lyon Academy students and teachers before or after class and in the halls and parking lot. In addition, I participated whenever there was an in-class "icebreaker" type activity, such as sharing a piece of news from the weekend.

Throughout my interactions with students, I tried to adopt a role of a curious adult friend, rather than a teacher. My goal was to be seen as a regular nonjudgmental presence in the classroom, there to learn from being attentive to classroom activities. As such, I did

not discipline students if I saw a minor infraction in school rules (e.g., voices too loud), nor did I try to instruct them. As a mark of my status, the students called me by my first name, “Beth,” rather than “Miss Faller,” which was how they addressed their teachers. I did not initiate conversations with students while observing, but did answer in a friendly manner if students spoke to me. Many of them would say hello to me as they entered the room, or if they saw me in the hall. Rarely did students appeal to me on an academic matter, and when they did, it was usually a quick question about something they knew I had observed (e.g., “What do you call those things we grew plants in?”). In general, students appeared to be comfortable engaging in nonacademic talk with peers while I was around.

Data Analysis

Data collection and analysis were overlapping and iterative processes (Dyson & Genishi, 2005; Heath & Street, 2008). After classroom observations, I wrote memos to record emergent themes that could be used to help guide what I attended to during future observations. For example, early on I identified the key phrase “as scientists” in Ms. Marsh’s language and recorded the details of as many instances of its use as possible in my fieldnotes. Toward the end of data collection, I transcribed 10-minute intervals from 30 minutes into each classroom observation. This detached selection of data for transcription was used to allow for attention to changes over time and mitigate against the selection of purely illustrative data that confirmed preconceived ideas (Heath & Street, 2008). My analysis of transcribed observational data and fieldnotes for all observations indicated that classes did *not* follow a strict daily routine, such as a regular sequence of beginning with notetaking, followed by hands on activity, followed by discussion, for

example. Therefore, the transcribed intervals can be viewed as a sample of the classroom activities that occurred across observations.

After data collection was complete, I coded observation transcriptions, along with fieldnotes and interview transcriptions, in Atlas.ti qualitative analysis software using an inductive open coding approach (Charmaz, 2006; Maxwell, 2005; Corbin & Strauss, 2008). I began by coding observation transcriptions and fieldnotes, and then used this initial code list to code interviews. The initial code list focused on classroom activities (e.g., reading, writing, experiment, assessment, constructing a diagram), behaviors (e.g., teacher question, student question, teacher connects science concept to something else, student connects science concept to something else), and explicit messages about who scientists are and what they do (e.g., teacher uses phrase “as scientists,” talk about or use of tools specific to doing science). In coding interview transcriptions, I added another set of codes to capture relevant information from the student perspective (e.g., what students said about what scientists wear, where scientists work, what they do in science class, etc.). I also added a set of codes to capture students’ talk about whether they believed science was useful or relevant in their lives. Following coding, I created two additional matrices. The first allowed me to look at trends in the language students used to describe an imagined scientist at work, while the second allowed me to compare the actions they attributed to a scientist when they imagined him/her at work with the actions they attributed to themselves when they imagined being in science class. As a final analytic step, I created narrative profiles of the individual students I interviewed (Seidman, 1998). These profiles were crafted in order to compare and contrast experiences across students, and used the students’ own words whenever possible. Throughout data analysis, I

engaged in a process of writing analytic memos, building theories, and returning to the data to verify, reject, and refine these theories.

Findings

“You’re Building your Persona as a Scientist”: Classroom Level Findings

In this section, I present classroom level findings based on my analysis of videorecorded classroom observations and fieldnotes. This analysis focused on what opportunities for building science identities were available to the female students in their Lyon Academy classrooms. As my analysis makes clear, the language and instructional practices that Ms. Marsh used created an expanded and more inclusive view of science and scientists than is present in many popular conceptions. In particular, Ms. Marsh used language that positioned her students as scientists, gave them access to values, activities, tools, and forms of expression that she indicated were central to doing science, and built bridges to science beyond the school curricula. I discuss each of these areas in turn.

Positioning students as scientists. Analysis of observational data revealed that Ms. Marsh often used language that explicitly positioned her students as scientists engaged in the scientific enterprise. As demonstrated in Table 2, the key phrase “as scientists” occurred in her talk across all classrooms. For example, Ms. Marsh told her 6th grade class, “As scientists, there’ll be lots of questions and you have to put your best thinking, everything that you know, everything that you learned about, towards that question or problem,” moving from the more general “scientists” to the personal pronoun “you” to position her students as legitimate members of this group (1/15/13). Similarly, on another occasion, when a 6th grader was spontaneously telling her classmates about an impromptu “experiment” with a carbonated drink on a bus, Ms. Marsh asked for

clarification, saying, “So wait, can you back up? Explain your setup, as a scientist, on your bus laboratory” (1/8/13). At other times, Ms. Marsh was even more explicit about the work her students were engaging in to become recognized members of the science community, as illustrated by an instance when her 7th graders performed poorly on an assessment. Ms. Marsh responded to this poor performance by leading a discussion where students generated ideas for how they might ensure better performance in the future. During this conversation, Ms. Marsh told her students what they did in class was important because “you’re building your persona as a scientist. You’re saying, ‘This is who I am’” (2/25/13).

A final example of Ms. Marsh positioning her students as scientists occurred when the 6th graders were discussing their observations of plants that they were watering with four different kinds of liquids, including orange juice. The following exchange occurred after a student said that her orange-juice-watered container looked “like a cemetery.”

Ms. Marsh: Who else has a description? So, she says it looks like a cemetery.

Nice use of simile. But, if we’re scientists, is there anything we can connect this back to, maybe in a science classroom? Toni?

Toni: It’s kinda, it kind, it kind of looks like mold is beginning to grow, because it, because it looks kind of fuzz, fuzzy-ish...

Ms. Marsh: OK.

Toni: ...like spider webs.

Ms. Marsh: Let’s make some connections. When else would, we would have seen mold in this classroom? How do we, unlike, I’m not sure

about Shaniqua's [container watered with vinegar]. I seriously, I, I'm not sure what that is, but I, I agree with Toni that I think the OJ one is mold, because what are we, what am I connecting it back to that maybe you are too?

Samayah: The, when we had the bread slices there.

Ms. Marsh: OK. So the bread, the bread here and we saw some funky looking mold over there. Where else did we see mold? Where else?

Gabrielle: Oh, we saw mold in our terrariums.

Ms. Marsh: In our terrariums. Yes. So, that leads me to believe as scientists, and maybe you too, that actually that is, is mold (1/7/13).

During this exchange, Ms. Marsh affirms the value of her student's poetic description of the mold ("like a cemetery"), while also encouraging the use of precise language and experiences more appropriate to the situation "if we're scientists." She ends by positioning both herself and her students as scientists and leaving open the possibility that they, empowered as scientists using independent judgment, might disagree with her ("that leads me to believe as scientists, and maybe you too.")

Making central values, activities, tools, and language available. In the previous examples, Ms. Marsh used language that expressed a general sense of group affiliation: *We are scientists*. However, my analysis also revealed that, on many occasions, she used language that focused her students on specific values, activities, tools, and language that they should employ in order to be recognized as scientists in her classroom. These instances generally occurred in the context of hands-on experiments, which Ms. Marsh treated as valid instances of doing science. A typical example occurred

when Ms. Marsh was working with her 5th grade class to jointly construct a chart displaying the results of an experiment. While they worked, she told them, “As scientists, we want to be specific, we want to use evidence, and we want to really communicate our thinking... because as scientists it doesn’t matter what we find out unless we can share it with people” (12/13/12). In this example, Ms. Marsh engaged her students in the activity of constructing multiple representations (e.g., oral explanations, printed titles and keys, charts) to convey experimental findings, while also endorsing the values of clear communication and using evidence to support their claims. Another activity that Ms. Marsh highlighted as central to doing science across all four classrooms was writing down and sketching observations during an experiment. For example, she advised her 8th graders, “Girls, again, you are also writing questions, but you’re also writing observations. So, you know, as scientists, you are recording observations by drawing, but you’re also writing down your noticings. Right? What do you see? What do you notice?” (4/1/13).

In addition to giving her students access to activities she endorsed as central to doing science, Ms. Marsh also invited her students to use discipline-specific tools and language conventions. For example, she told her 8th graders, “As scientists we’re gonna use models a lot, specifically with [the] area of genetics ‘cause it’s very conceptual...We have to create things to look at to help us make sense of it” (3/21/13). Similarly, she prefaced an experiment where 6th graders used beakers and graduated cylinders by saying, “These are both tools that are used in science to measure the volume or the amount of space [that] usually liquids take up” (2/4/13). Examples of specific language conventions that Ms. Marsh endorsed include using symbols (“I’m gonna, as a

scientist,...give these things some symbols,” 7th grade, 1/3/13), using the metric system (“You should be working, as scientists, with millimeters and centimeters,” 6th grade, 12/10/12), and using technical vocabulary (e.g., abiotic, inertia). Ms. Marsh often explicitly taught the latter by making connections to students’ everyday lives and language and then introducing a technical term that they should use in science. For example, she introduced the term “optimum condition” to 5th and 6th grade students by asking them whether there was a time of day where they “feel you’re at your very best.” She then asked them to use their new “term in science” to a chart recording the results of an experiment:

So I want you to make a connection between those examples you just said about ourselves and then go again back to our plants. So let’s go back to our plants, actually back to the, the white paper that we set up. Now we’ve got to give a name to that sticker. Now we’ve got a term in science (5th grade, 12/13/12).

Thus, within her classroom, Ms. Marsh clearly positioned her students as working scientists and gave them access to values, activities, tools, and language that she indicated were central to doing science.

Building bridges to science beyond the school curricula. Analysis of observational data revealed that Ms. Marsh also provided her students with opportunities to connect with a broader community of scientists and to see science as relevant to their lives. These opportunities included school-wide assemblies, science camps, and other extracurricular programs, field trips, readings, and guest speakers. Many of these opportunities involved interacting with nature (e.g., fieldtrip to a local nature center where students looked for animal tracks in the snow) and environmentalism (e.g.,

summer camp dedicated to experiencing and cleaning up a local bay). Through these opportunities, Ms. Marsh expanded the more narrow view of what science is and who scientists are provided by the official curricula, giving her students more potential sources to draw from in constructing science identities.

Importantly, many of these experiences extended over time and gave students an opportunity to make connections at a local level, seeing science and scientists in their own backyard. The most striking example of this unfolded over the course of the school year, beginning in the fall when Ms. Marsh invited a speaker from a local environmental agency to visit her classes and talk about trash and recycling. As part of his talk, the speaker mentioned the environmental impact of Styrofoam in landfills. After this talk Ms. Marsh asked her students to calculate how many disposable Styrofoam trays, which were then in use in the Lyon Academy cafeteria, they threw away in a year. Ms. Marsh then started a project where the students designed washable and reusable plastic plates to replace the Styrofoam trays. In the words of sometimes-disengaged 6th grader, Gloria, Ms. Marsh organized this project “so we could stop using Styrofoam trays and we can save the earth.” Ms. Marsh funded the project by applying for a grant from a local organization that supported environmental education and through additional support from a local nature center with which she had formed an extended multi-year relationship. The reusable plate project was nearing completion during the spring of the data collection year and provided students with a tangible and very local opportunity to see the relevance of science in their daily lives. Thus, through her language and instructional choices in the Lyon Academy classrooms, Ms. Marsh created an expanded view of science relative to many popular conceptions of who scientists are and what they do. Of course, her

individual students were free to draw on this expanded view or not as they constructed (or rejected) their own science identities.

Conflicting Views of Science: Student-Level Findings

In this section, I present student-level findings based on my analysis of data from interviews with 12 focal students. This analysis concentrated on what resources individual students drew on in constructing science identities. As my analysis makes clear, students did draw on the more inclusive view of science made available by Ms. Marsh in the Lyon Academy classrooms. However, the picture that emerged from the data is more complicated than a straightforward acceptance or rejection of this view, since many students also drew on sometimes conflicting popular images and beliefs about science from outside of the classroom. I discuss each of these areas in turn.

Drawing on classroom experiences. Analysis of interview data indicated that all but one student, 6th grader Gloria (See Chapter 4 for a detailed case study of Gloria), did indeed show evidence of drawing on the expanded view of science that Ms. Marsh made available in her classrooms. In particular, students positioned themselves as scientists by talking about classroom practices as legitimate expressions of what it means to do science. This was primarily evidenced in two ways. First, during the image elicitation portion of the interview, all but one student referred to classroom experiences in order to justify why an image was related to science. Typically, the student would state that she knew it was science because she had learned about similar content or engaged in a similar activity in a science class before. For example, 5th grader Jeannette said that an image of a plant had to do with science, because “upstairs [in the science classroom] when we were doing environmental science, we used to grow plants and this is just seeing how the

plant grows and how it would sprout and usually we would sketch it.” Similarly, when shown an image of a coral reef, 7th grader Silvana said, “Oh my gosh! Yes. This reminds me of science. ‘Cause when we learned about coral and we saw this whole video documentary and I stayed after school for extra credit. And this reminds me of how they’re saying pollution is killing all the coral.” As a final example, 7th grader Camila said that an image of a man looking at an animal in a cage was science, “because he’s looking at animals and taking notes. We do that. We look at what they’re doing. We describe them.”

In addition to using classroom experiences to justify labeling something as science-related, students also tended to view many of the activities they did in science class as things working scientists would also do. In particular, as I show in Table 3, analysis of interview data revealed a substantial overlap in the actions that students described imagined scientists doing and those they described themselves doing when they imagined themselves in science class. Actions that appeared in both images of scientists and images of students in science class include building, creating, doing something over again, finding information, figuring something out, looking closer, observing, taking notes, testing something, and working with organisms. Interestingly, only three actions appeared in students’ images of themselves in science class without appearing in the images of scientists at work: sketching what they saw under a microscope, as well as the school-related activity of copying from a board and the disengaged action, provided by Gloria, of sitting staring at nothing. Based on the latter two activities, some of the Lyon Academy students did seem to maintain a distinction between doing school and doing science, at least part of the time.

In addition to the general endorsement of classroom activities as legitimate expressions of doing science, three students, Mariana, Camila, and Vanessa, explicitly labeled Ms. Marsh as a scientist and Vanessa also included herself and her classmates as members of this group. For example, 8th grader Mariana told me that “a lot of scientists like Miss Marsh and other scientists” were working on the problem of pollution, while 7th grader Camila told me that she thought of Ms. Marsh when she imagined a scientist. Similarly, 8th grader Vanessa also said she thought of Ms. Marsh when she imagined a scientist (in addition to a NASA scientist), but Vanessa also spoke about Ms. Marsh’s invitation to her students to view themselves as scientists:

Beth: So can you tell me a little bit about what you’re picturing?

Vanessa: A NASA.

Beth: OK.

Vanessa: Because, well, NASA’s the place of scientists, but then my second one is kind of like Miss Marsh because for, what like 4 years, she’s been the only scientist-like figure that I, like, OK. That’s what a scientist is. And, I think that on a teacher level she’s closer to NASA than other schools that I’ve been to are.

Beth: What makes you say that?

Vanessa: Because it’s, it’s more, it’s more of hands on, it’s more of a putting in math with science and it’s more, how do you say this? Miss Marsh she puts it in like, OK, when you come into this room, you’re not 8th grade, you’re not just girls, you’re scientists.

Later, Vanessa contrasted her experiences in Ms. Marsh's science class at the Lyon Academy with her experiences at a previous coeducational school where she indicated that grouping practices hindered girls from engaging in science practices and thus forming science identities:

Beth: Why do you like [science]?

Vanessa: 'Cause, I mostly like it because of Miss Marsh's way of teaching it and like I said before, when you go into the science classroom, you're not a boy or a girl. You're just a scientist...

Beth: Umm hmm.

Vanessa: ...So, for many years it was only male scientists. And then now we're in the setting where gender isn't really an issue, like everyone's a scientist no matter if you, if you can't do the equation, but you can, you can see something, observe something that no one else has had, you can dig deeper into the organism and then if you're good at the equation, you're helping, you and that person [inaudible] because you don't see something that's there but they do and they don't know the equation, so you just fit together.

Beth: Before you came here were you in a school with, like a coeducational, boys and girls...

Vanessa: Yeah.

Beth: ...school and did you take science classes there?

Vanessa: Yes.

Beth: Did you feel like gender came into play there?

Vanessa: Yeah. Because it's just like, if you get partnered with a boy, it's like, 'OK. I'm gonna do all the work. You just sit there.'

Beth: OK.

Vanessa: And then at the end of the day, even, I feel like even though the teacher saw that he was doing all the work, I was still getting rewarded for it.

Beth: Umm hmm.

Vanessa: And it wasn't something that I wanted because I was just like, 'I didn't do anything. You're rewarding a person who didn't do anything, who just sat there and watched a boy do all the work.'

Beth: Umm hmm.

Vanessa: So, when I came here, it was everyone was doing something. If you didn't do the work, you weren't rewarded for work you didn't do.

In this statement Vanessa very directly drew on Ms. Marsh's positioning of her female students as scientists and linked this positioning to all students' ability to engage in the central practices of doing science within their Lyon Academy classrooms, something Vanessa said was lacking in her previous school. Notably, Vanessa was the only student to explicitly link attending an all-female school with increased opportunities in science.

Finally, analysis of interview data indicates that, with one exception, 6th-grader Gloria, Lyon Academy students generally talked about science in a positive light and saw it as relevant to their lives. For example, when the students told me about an image of

themselves in science class, they listed the following positive descriptive words: *like what doing, fun, interesting, understand, have patience, want to participate, pay attention, cool, important, useful, surprised, accomplished, easy, entertaining, exciting, fascinating*, and *not scared*. In contrast, students only used three negative descriptors: *difficult, frustrating*, and *don't understand*. While four students included some of these negative descriptors, all students except Gloria talked about the negative in the context of other positive feelings about doing science. For example, Silvana described how she sometimes felt “frustrated” in science class, but indicated that this frustration was a step on the way to getting the desired “outcome” and feeling “accomplished”:

Silvana: I'm probably excited and fascinated but then I'm a little frustrated too 'cause it's not working out the way I want to. But then I'm like, 'OK. One day I will get an outcome.'

Beth: [laughs] So, do you find that science is often frustrating?

Silvana: Well, not, well I get a little frustrated with everything 'cause I like it to come out perfect. But then it's also, I, I like it because it's like I don't know the answer right away...

Beth: Umm hmm.

Silvana: ...and I don't, I like to challenge, so I like to try to get it there.

And I know that when I get there I'm gonna be so accomplished.

Thus (with the exception of Gloria), even among the students who associated some negative emotions with science, their overall descriptions were generally positive and focused on the accomplishment they felt when they finally figured something out or the aspects of science they enjoyed.

In addition to these positive emotions, the majority of Lyon Academy students talked about connections between science and their out of school lives. For example, 83% of the interviewed students said that they used some of what they learned in science class outside of school. Three students described using science equipment, such as telescopes or magnifying lenses, while others talked about knowing more about phenomena they saw in their everyday life, or approaching situations differently. For example, 5th grader Jeannette linked her interest in science class to the connections she was able to make to things she had previously seen outside of school:

Jeannette: For me I find it interesting because we learn stuff that we don't know and like I've never known some of the stuff that she teaches us and it's very interesting and I find I like to pay attention in the class because, you know, it keeps, it keeps me entertained.

Beth: OK. And so what are some things that you found out that are interesting to you?

Jeannette: Well, under the microscope, we look at microbes and then sometimes we could see stuff...

Beth: Umm hmm.

Jeannette: ...but then up close you don't see things that you will with the naked eye and it's cool the way it looks and then, I think when you weren't here, we were doing environmental stuff and then we learned about how the environment was being treated badly and how people are just throwing stuff on the floor and not caring

about where the plants like, there was no space for the plants to grow.

Beth: Umm hmm. And so why was that interesting?

Jeannette: Well, because I, I've seen it happen. I see people litter a lot and it's very interesting to like learn about how people treat it and maybe talk some sense into people.

Similarly, 7th grader Silvana also discussed the relationship between what she learned in science class and her everyday life. She said she liked to “know things” and so liked science, “because in science they teach you the background story and little things that happen before, so I can be able to tell you that the plant didn't just pop...the seed was planted.” Thus, the majority of Lyon Academy students drew on classroom experiences in constructing science identities. However, as will be discussed in the next section, popular images also played an important role in this endeavor.

Drawing on persistent popular images. In addition to drawing on the expanded view of science provided in their classrooms, students' beliefs about science identity were also influenced by more limited archetypal images of scientists found outside of their classrooms (e.g., solitary White men in labcoats with facial hair and test tubes). This was especially evident when I asked students to imagine a scientist doing scientific work. In Table 4, I summarize the key attributes that were present in students' descriptions. The results from my analysis revealed the persistence of features drawn from limited and noninclusive archetypal images and popular culture representations of scientists. This was especially true in the case of physical features. In spite of attending the all-girls Lyon Academy where science was taught by a woman, half of students ($n=6$) imagined the

scientist as a man, while another 25% ($n=3$) imagined both male and female scientists. Only three students focused their description on a female scientist. Interestingly, two of these students described living female scientists, Ms. Marsh and Jane Goodall. Other features often present in archetypal images include wearing a lab coat ($n=10$; 83%) or glasses or goggles ($n=5$; 42%), having “crazy” hair ($n=2$; 17%) or facial hair ($n=2$; 17%), and being “light-skinned” or “not-dark-skinned” ($n=2$; 17%).

Moreover, three students further elaborated on why they held less inclusive views of who scientists are. All three of these students said that they rarely saw women or people of color engaged in science, making a distinction between classroom science and more popular images. For example, when I asked about whether there was a certain type of person who was more likely to become a scientist, 8th grader Mariana drew on the images of scientists she saw on television to explain why she thought men were more likely than women to become scientists:

Beth: Is there any type of person who's more likely than a different type of person to become a scientist or is anyone equally likely to become a scientist?

Mariana: I think it's more men.

Beth: Men are more likely?

Mariana: Yeah.

Beth: OK. And why do you think that?

Mariana: Because just like when I see TV and I see, like science channels, I mostly see men there, like you rarely see a woman.

Similarly, 8th grader Savannah described her imagined scientist as a “light-skinned” man. She then elaborated, “Cause those are what I see. That’s what I think of when I mostly hear of scientists. You don’t see a lot of females doing science stuff, like in class, but not in [the outside world], men usually do.” Thus Savannah made explicit the difference between doing “science stuff” in class and being a scientist in the outside world.

Moreover, for the majority of students ($n=10$; 83%), the typical scientist would work in a science laboratory and the image of a solitary scientist toiling away still predominates. Half of students ($n=6$) indicated that the scientist worked alone and another 42% ($n=5$) described only limited interaction with an assistant (e.g., asking for materials) or another scientist (e.g., sharing ideas after the work was complete). Science equipment and materials also played a central role in these images for all but one student. The most frequently mentioned include chemicals or “liquids” ($n=6$; 50%) and test tubes ($n=6$; 50%). One fairly typical example of these characteristics is the description of a scientist provided by 8th grader, Mariana:

- Mariana: I see a scientist trying to create a cure for a sickness.
- Beth: OK. And so, sorta what’s the, what space are they working in?
What’s it look like?
- Mariana: It’s like a lab and he has goggles on and it’s like a little tight crowded room with a lot of like glass bottles.
- Beth: OK. And you said, you said, “he,” didn’t you?
- Mariana: Yeah.
- Beth: So what does he look like, the scientist?
- Mariana: He kinda looks like Einstein.

Beth: OK. And, and, how's he dressed? Sorta what's he wearing?

Mariana: He's wearing a white lab coat with some black pants.

Beth: OK. And, is the, is he working with anyone else or is he by himself?

Mariana: He's by himself.

Interestingly, like Mariana, a few students seemed to draw directly from iconic photographic, television, or comic book images of scientists, describing such things as a scientist wearing a helmet and building a flying machine, a dark room with a spotlight on the scientist, and a gleaming white room where the scientist worked. Additionally, two students referred to their imagined scientist as looking like "Einstein," while Vanessa, the 8th grader who spoke eloquently about herself and her classmates as scientists, said her imagined scientist looked like Dr. Doofenshmirtz, a character from the popular Disney cartoon *Phineas and Ferb*. Dr. Doofenshmirtz is a labcoat-wearing White male scientist who speaks with a German accent and creates obscure inventions to further his evil plots. Thus the majority of Lyon Academy students, even those who embraced Ms. Marsh's positioning of them as working scientists, drew from at least some elements from more limited and noninclusive popular images in constructing their views of who scientists are and what they do. However, some students, like 8th grader Mariana, were highly reliant on these noninclusive images, while others, like her classmate Vanessa, drew more heavily from the expanded view of science available in their science classrooms.

Discussion

A growing body of literature has implicated science identity as a possible explanatory factor in the persistent underrepresentation of women in science (e.g.,

Brickhouse, Lowery, & Schultz, 2000; Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Wong, 2012). Yet very few studies have examined the ways in which teachers' language and instructional practices encourage their female students to view themselves as the "kind of" people who do science. Even fewer studies have considered the perspective of the students within these classrooms, examining the sources they draw on in constructing (or rejecting) science identities. Thus, the purpose of this study was to address this need within the understudied context of a small all-girls' school serving primarily students of color from working class backgrounds.

Overall, my findings reaffirm the important roles played by both language and instructional practices within the science classroom and popular images and beliefs about science outside of the classroom. Specifically, at the classroom level, I found that the language and instructional practices that Ms. Marsh used created an inclusive view of science that her students could draw on. In particular, Ms. Marsh used language that positioned her students as scientists, gave them access to values, activities, tools, and language that she indicated were central to doing science, and built bridges to science beyond the school curriculum. In addition, at the student level, I found that most students did draw on this more-inclusive view of science in constructing their own science identities. However, many students also drew on more limited and noninclusive views of science and scientists from popular culture outside of the classroom.

Extending previous research on the ways in which science teachers promote affiliation with science (e.g., Goldberg, Welsh & Enyedy, 2008; Moje, 1995), the findings suggest that while teachers' use of linguistic markers such as inclusive personal pronouns play an important role, other practices such as providing access to central

values, activities, tools, and language, and demonstrating the relevance of science in students' lives may also be important. This is especially apparent when contrasted with other documented classroom practices that encouraged disaffiliation, such as using language that marks science as a difficult discipline meant for only a few (Carlone, 2004; Lemke, 1990) or emphasizing the need to produce the one right answer said in the right way (Carlone, Haun-Frank, & Webb, 2011; Moje, 1995). Such practices discouraged some students from seeing themselves as scientists and make it risky for them to participate meaningfully in disciplinary practices.

Thus, the findings highlight the important role of the science teacher in helping students to view science as open to people "like them." This includes such seemingly basic things as ensuring that all students are able to participate in science class. While not an issue in a single-gender setting, Vanessa's story of a former science teacher who did not intervene even though Vanessa believed she was marginalized by her male partner during group work, provides a warning that teachers in coeducational settings may need to be particularly attuned to this issue. Such a warning is echoed by a broader literature documenting male dominance during small group work in science classrooms (Guzzetti, 2004, Roychoudhury, 1994).

Beyond ensuring that all students are able to participate, the findings also illustrate how science teachers can provide their students with access to values, activities, tools, and language central to their discipline. While disciplinary norms and language were sometimes implicit in Ms. Marsh's teaching, she often explicitly marked particular values or uses of language as important to scientists. Providing access to such disciplinary knowledge is a crucial part of science identity formation, because one cannot

be recognized as the kind of person who does science without having some knowledge that allows one to demonstrate competence within the domain (Carlone & Johnson, 2007).

Finally, the student-level findings provide a reminder of the dynamic and complex nature of identities. Importantly, several students indicated that what they did in the classroom was science and that they enjoyed science, but that it wasn't for "people like us" (e.g., scientists are light-skinned). One key to understanding this apparent contradiction may be the distinction between "doing science" and "being a scientist" documented in prior research (Archer et al., 2010). Archer and colleagues (2010) found that students commonly distinguish between "doing science," which they generally like, and "being a scientist," a career to which few aspired. Moreover, the authors noted the role of social class, ethnicity, and gender, such that the idea of being a scientist was beginning to be ruled out as "unthinkable" for certain students, even at a young age (Archer et al., 2010). Such a distinction might allow Lyon Academy students to enjoy doing science in the classroom and see it relevant to their lives, while also considering the career of scientist as something closed off to them. If this is the case, my findings indicate that less inclusive popular images of scientists may be implicated in creating such a view ("You don't see a lot of females doing science stuff," said Savannah), even among students who seem to embrace their teacher's invitation to view themselves as scientists in the classroom.

Limitations and Directions for Future Research

I wish to acknowledge the limitations of this study, which involves the analysis of data from a single small all-female school serving middle graders. I chose to work at this

school because it provided an interesting context to explore science identity, especially in light of calls for single-gender science education despite the lack of research in these settings. Not only is the Lyon Academy single gender, but it is unusual in several other respects. Notably its limited enrollment means that class sizes are relatively small for the US and teachers continue to work with and get to know their students over the course of 4 years. For all of these reasons, I acknowledge that the Lyon Academy should not be seen as representative of other schools and results should not be generalized beyond this study.

In spite of this, the study points to several areas worthy of further research. First, the findings highlight the importance of science teachers in providing counter-narratives to more limited popular narratives of who scientists are and what they do. Such experiences can be important for those who are not included in popular images and beliefs. In particular, my findings document Ms. Marsh's ways of building bridges to science beyond the school curriculum to help her students see its relevance in their everyday lives. Such instructional practices appear especially promising in light of previous research documenting that even girls who achieve at average or high levels in science classes may view science as irrelevant to their everyday lives and/or their future goals for themselves and thus be unlikely to pursue science beyond compulsory courses (Brickhouse, Lowery, & Schultz, 2000; Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Wong, 2012). Future research is necessary to document these types of bridging instructional practices and especially to examine their link to student attitudes about science and career plans.

Finally, there is a need for further research into students' distinction between "doing science" in school and "being a scientist." Consistent with findings from a large sample of students in England (Archer et al., 2010), several students at the Lyon Academy seemed to maintain this distinction. While they had generally positive views of school science and viewed themselves as capable of doing science at school, they still had a more limited view of who could be a scientist as a career, a view that seemed to be at least partially drawn from popular images of science and scientists. More research is needed to investigate this distinction and whether it might be mitigated by programs designed to make careers in science more imaginable for traditionally underrepresented students. For example, future research could investigate the impact of exposing such students to a more diverse array of working scientists to help to combat some of the more limited and noninclusive popular images.

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Table 1. Demographic Makeup for Student Interview Sample ($n=12$)

Grade	Name ^a	Race/Ethnicity	Eligible for Free or Reduced Price Lunch	Teacher Classification of Science Achievement
5th	Mandy	Multi-Racial	No	Above Average
	Jeannette	Latina	Yes	Average
	Aaliyah	Black	Yes	Below Average
6th	Effie	Black	Yes	Above Average
	Lauren	Black	Yes	Average
	Gloria	Latina	Yes	Below Average
7th	Silvana	Latina	Yes	Above Average
	Bianca	Latina	Yes	Average
	Camila	Latina	Yes	Below Average
8th	Vanessa	Black	No	Above Average
	Savannah	Latina	Yes	Average
	Mariana	Latina	Yes	Below Average

^a All names are pseudonyms.

Table 2. Examples of Ms. Marsh's language that explicitly positions her students as scientists by grade.

Grade	Examples
5	<p>As scientists, we want to be specific, we want to use evidence, and we want to really communicate our thinking...because as scientists it doesn't matter what we find out unless we can share it with people. ***</p> <p>And then what else should we include? As scientists, I make sure you do it everyday in here, whenever I give you a piece of paper. ***</p> <p>How do you communicate your thinking as a scientist? ***</p> <p>So as a scientist I'm gonna go back to make sure. OK? I always go back and reread. It's a mark of a good reader. It's the mark of a good, um, scientist. OK? ***</p> <p>Nice job. I see some future microbiologists in my midst, which, by the way, I'm trying to get a microbiologist to come visit us.</p>
6	<p>So what we're gonna do right now is I have a little response sheet for you and it poses a question, 'cause as scientists there'll be lots of questions and you have to put your best thinking, everything that you know, everything that you learned about, towards that question or problem. **</p> <p>Say you've got, that's enough evidence for me as a scientist and then you start [to] water your indoor radish plants and then you ate the radish plant. Do we eat bleach? ***</p> <p>But if we're scientists, is there anything we can connect this back to, maybe in a science classroom? ***</p> <p>So, um, that leads me to believe as scientists, and maybe you too, that actually that is mold. ***</p> <p>So wait, can you back up? Explain your setup, as a scientist on your bus laboratory. ***</p> <p>Again, you should be working as scientists with millimeters and centimeters. ***</p> <p>'Cause like you said, one way that scientists communicate their findings is through the written word, so you're gonna write down any properties that you can to describe the objects.</p>

	<p>***</p> <p>So these are both tools that are used in science to measure the volume or the amount of space, usually liquids take up.</p> <p>***</p> <p>If you had one of those yellow rulers or just big sticks, what are different units that, whether we're a scientist or not, might be on that ruler?</p> <p>***</p> <p>You're close. But as scientists using kind of the metric system and base ten, it's a little bit more cleaned up.</p>
7	<p>Now I'm gonna as a scientist do a...I'm actually gonna give these things some symbols. So I'm gonna call this, I'm gonna give a symbol. OK? I'm gonna call initial volume, I'm gonna give it a symbol. I'm gonna call it Vi.</p> <p>***</p> <p>If you think of this more globally. Like the big perspective. You're building your persona as a scientist. You're saying this is who I am.</p> <p>***</p> <p>So, it's a really big thing in science to see the relationship between cellular respiration that happens when, you know, organisms breathe in and out and how plants grow.</p>
8	<p>As scientists we're gonna use models a lot, specifically with [the] area of genetics 'cause it's very conceptual...We have to create things to look at to help us make sense of it.</p> <p>***</p> <p>Girls, again you are also writing questions, but you're also writing observations, so you know as scientists you are recording observations by drawing but you're also writing down your noticings. Right? What do you see? What do you notice?</p>

Table 3. Actions that focal students ($n=12$) attributed to scientists when they imagined a scientist at work and themselves when they imagined themselves in science class.

Action	What Scientists Do: Imagine a Scientist	What We Do: Imagine Yourself in Science Class
build/put stuff together	√	√
create/invent	√	√
do it over again	√	√
find information	√	√
find out/figure out/see		
how/understand/discover	√	√
look closer	√	√
Observe	√	√
take notes	√	√
test/ experiment	√	√
use chemicals	√	√
work with organisms	√	√
Analyze	√	
Collect	√	
Dig	√	
Dissect	√	
hold equipment	√	
Multitask	√	
Predict	√	
staring into [outer]space	√	
Teach	√	
copy from board		√
look at something under microscope		√
sit staring		√
Sketch		√

Table 4. Key attributes found in focal students ($n=12$) images of scientists at work.

Scientist Physical Description	Vanessa	Savannah	Mariana	Silvana	Bianca	Camila	Effie	Lauren	Gloria	Mandy	Jeannette	Aaliyah	Total
man	✓	✓	✓	✓	✓			✓	✓	✓		✓	9
woman	✓					✓	✓	✓		✓	✓		6
lab coat	✓	✓	✓	✓		✓		✓	✓	✓		✓	10
dressed in White					✓						✓		1
t shirt													1
jeans										✓			1
dirty pants												✓	1
dressed "fancy"						✓							1
crazy/spiky hair				✓								✓	2
long /pretty hair						✓				✓			2
(woman)													2
glasses			✓	✓	✓	✓		✓					1
goggles													4
helmet												✓	1
moustache/beard				✓					✓				2
light skinned		✓							✓				2
tan											✓		1
Character Trait/Emotion													
frustrated									✓				1
rude									✓				1
love science						✓							1
trying hard				✓									1
Social Context													
working alone	✓	✓							✓	✓	✓	✓	6
working with another					✓					✓			2
limited interaction			✓	✓		✓	✓	✓					5
Physical Location													
in lab/science room	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		10

Appendix

Mapping of questions from student interview protocol to three facets of science identity.

Facet of Science Identity	Relevant Interview Protocol Questions
Who are scientists and what do they do?	<p>(2) To start out, I would like you to picture in your mind a scientist who is doing scientific work. Think about what the scientist is doing, where the scientist is, and what the scientist is like. I'll give you a minute to get that picture in your mind. Tell me when you are ready.</p> <p>Can you tell me about what you pictured in your mind?</p> <p>GENERAL PROBE IF NEED MORE INFORMATION:</p> <ul style="list-style-type: none"> • Can you tell me a little more about that? <p>PROBE IF NOT ALREADY COVERED:</p> <ul style="list-style-type: none"> • What is the scientist doing? • Why is he or she doing this? • Where is the scientist working? • Is the scientist working with anyone else? IF YES, who else is the scientist working with? What are they doing? IF NO, do you think the scientist ever works with anyone else? Who is it? What do they do? • Is there a certain type of person who usually becomes a scientist? <p>Now I would like to talk to you a little bit more about how scientists think and what scientists do.</p> <p>(7) First, I'm going to show you a bunch of pictures. I want you to take a look at them and tell me whether they show something that has to do with science or not. How do you know this is/isn't science?</p> <p>(8) What makes someone a good scientist?</p>
Do I do the things that scientists do?	<p>(3) Now I want you to get a new picture in your mind. Picture yourself doing science in science class. Think about what you are doing, where you are, and how you feel. I'll give you a minute to get that picture in your mind. Tell me when you are ready.</p> <p>Can you tell me about what you pictured in your mind?</p>

	<p>GENERAL PROBE IF NEED MORE INFORMATION:</p> <ul style="list-style-type: none"> • Can you tell me a little more about that? <p>PROBE IF NOT ALREADY COVERED:</p> <ul style="list-style-type: none"> • What are you doing? • Why are you doing that? • Where are you doing it? • Are you working with anyone else? IF YES, who else are you working with? What are they doing? IF NO, do you ever work with other people when you do science? Who is it? What do you do together? <p>Now I would like to talk to you a little bit more about how scientists think and what scientists do.</p> <p>(7) First, I'm going to show you a bunch of pictures. I want you to take a look at them and tell me whether they show something that has to do with science or not. How do you know this is/isn't science?</p>
Is science relevant and/or engaging to me?	<p>(1) To start out, I'd like you to imagine yourself in 20 years and describe what kind of work you will be doing. Is there any part of what you will be doing that is related to science?</p> <p>(4) Do you like science? Why or why not?</p> <p>(5) Are you good at science? Why or why not?</p> <p>(6) Do you ever use the things you learn in science class outside of school? Can you give me an example?</p>

Chapter 4: Study 3

Who Does Science?:

Science Attitudes and Identity among Middle Grade Students at a Small All-Girls' School

Abstract

The research presented in this paper began with the premise that science identity—that is, students' beliefs about who scientists are, what it means to do science, and whether science is interesting or important—is an often neglected lens for understanding females' science literacy outcomes and the persistent underrepresentation of women in science professions. In this article I present data collected over the course of 7 months as part of a larger study of science literacy at the Lyon Academy, a small all-female middle school serving primarily students of color and students from working class backgrounds. The purpose of this multiple-case study (Yin, 2009) is to explore the students' attitudes toward science and constructions of science identity, operationalized here as two dimensions: (a) students' beliefs about whether science is accessible to people “like them” and (b) their beliefs about whether science is interesting or important. The study drew on two central data sources: a student survey administered to all students ($n=50$) and semi-structured interviews with case study students ($n=3$). In addition, I triangulated the survey and interview data with data from fieldnotes (Emerson, Fretz & Shaw, 2011) and videorecorded science classroom observations (102 classes, 113 hours, recorded on 29 days). Using survey data, I first examined overall patterns in the students' beliefs about the two dimensions related to science identity development. I then used survey,

interview, and observational data from three contrasting case study students to explore students' constructions of science identity in more depth. Overall survey results indicated that many Lyon Academy students had strong positive beliefs about how interesting science is, but were more ambivalent about how accessible it is to people like them. Moreover, comparisons across the case study students indicated that in spite of attending science classes taught by the same teacher and using the same curriculum, there were striking differences in whether the students described doing science as an active or passive process. Finally, while all case study students indicated that attributes that anyone can develop determine who becomes a scientist, two of these students also drew on limited and noninclusive popular images when they describe an imagined scientist.

Introduction

Educators are increasingly asked to foster science literacy in *all* adolescents, preparing a citizenry ready to engage in meaningful ways with the scientific and technological questions that confront us in everyday life, from global warming to stem cell research. Such calls often focus on meeting the needs of females and other groups traditionally underrepresented in science professions. While females have made noteworthy gains in science participation and achievement over the last 50 years, they remain underrepresented in almost all science and engineering fields and very few women reach the upper levels of these professions (Hill, Corbett, & St. Rose, 2010). Reasons for this underrepresentation are complex, but evidence implicates broad social and environmental factors beyond just access to science courses and science achievement in secondary schools (Hill, Corbett, & St. Rose, 2010). For example, research has demonstrated that even girls who achieve at average or high levels in science classes may view science as irrelevant to their everyday lives and/or their future goals for themselves and thus be unlikely to pursue science coursework beyond what is compulsory (Brickhouse, Lowery, & Schultz, 2000; Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Wong, 2012). For ethnic minority girls from working class backgrounds, such beliefs may be reinforced by multiple factors including noninclusive views of who scientists are, limited knowledge of the range of science-related careers that exist, and low teacher expectations for their science achievement (ASPIRES, 2013). Given these findings, it appears that science identity—that is, students’ beliefs about who scientists are, what it means to do science, and whether science is interesting or relevant—is an important and often neglected lens for understanding females’ science literacy outcomes

and the persistent underrepresentation of women, and especially women of color, in science professions.

In this article I present data collected over the course of 7 months as part of a larger embedded multiple-case study (Yin, 2009) of four classrooms and twelve focal students (three per classroom) at the Mary Lyon Academy for Girls (Lyon Academy). The Lyon Academy is a small all-female middle school serving primarily students of color and students from working class backgrounds. I selected it as the site of the larger study for two reasons. First, while many proposals to address the gender gap in science call for single-gender science classrooms, there is very little empirical work investigating such settings. Second, the Lyon Academy primarily serves students whose voices are often absent from studies of science learning, and who are generally underrepresented in the field of science, namely females of color from working class backgrounds.

The design of the larger study allowed me to ask questions and make comparisons at both the classroom and the student level to shed light on the local particulars of science literacy instruction and science identity development among adolescent girls in a single-gender context designed to enhance their learning. Relevant to the present article, in the larger study, I documented how Ms. Marsh, the science teacher, used language and instructional practices that created an expanded and more inclusive view of science and scientists relative to many popular conceptions. For example, as I described in detail in Chapter 3, she used language that positioned her students as scientists, gave them access to values, activities, tools, and language that she indicated were central to doing science, and built bridges for them to see the relevance of science beyond the school curricula. However, individual students are always free to take up or reject the identities made

available to them through their various experiences with school, family, peers, and popular culture. Thus, in this study I used student-level data to explore the attitudes toward science and constructions of science identity among the students at the Lyon Academy. While identity is a complex and multi-faceted construct, for the purposes of this article, I focused on two major dimensions related to students' science identity development: *believing that science is accessible to people "like me"* and *believing that science is interesting and/or important*. Using survey data collected from all students, I first examined overall patterns in the students' science attitudes. I then used survey, interview, and observational data from three contrasting case study students to present an in-depth exploration of these students' beliefs about what it means to "do" science, whether science is relevant to their lives beyond school, and the type of person who becomes a scientist.

Theoretical and Empirical Perspectives on Science Identity

What is Science Identity?

There is a growing body of empirical research focused on science identity, and especially its interplay with other dimensions of identity such as gender, social class, race, and ethnicity (e.g., Archer et al., 2010; Archer et al., 2012; Carlone, Haun-Frank & Webb, 2011; Carlone & Johnson, 2007; Carlone, Scott & Lowder, 2014; Wong, 2012). Much of this work draws on a flexible and dynamic conception of identity, such as Gee's (2001) definition of identity as "being recognized as a certain 'kind of person,' in a given context" (p. 99). Expanding on this definition, every person takes on multiple identities and these identities "can change from moment to moment in the interaction, can change from context to context, and, of course, can be ambiguous or unstable" (Gee, 2001, p.

99). In applying such a broad and fluid definition of identity, researchers must make many choices about what counts as science identity and the construct remains “slippery and difficult to operationalize in a way that provides solid methodological and analytic direction” (Carlone & Johnson, 2007, p. 1189).

Prior research has focused on several dimensions of science identity. First, drawing on theory and ethnographic interviews with female undergraduate students of color studying science, Carlone and Johnson (2007) created a model of science identity consisting of three interrelated dimensions: competence, performance, and recognition. To illustrate these dimensions, they described a prototypical woman who has a strong science identity:

She is competent; she demonstrates meaningful knowledge and understanding of science content and is motivated to understand the world scientifically. She also has the requisite skills to perform for others her competence with scientific practices (e.g., uses of scientific tools, fluency with all forms of scientific talk and ways of acting, and interacting in various formal and informal scientific settings). Further, she recognizes herself, and gets recognized by others, as a “science person” (Carlone & Johnson, 2007, p. 1190).

Although Carlone and Johnson (2007) affirmed the importance of all three dimensions, their analysis highlighted the key role of recognition in the formation of strong science identities among women of color. Specifically, they found that members of traditionally underrepresented groups who do not fit in with historical and prototypical conceptions of scientists can experience difficulty achieving recognition as “science people” from established members of the scientific community. Moreover, they found

that the lack of recognition by others can hinder science identity development and discourage previously successful women of color from continuing to pursue science careers.

Research conducted in K-12 settings confirms that recognition (by others and self) is a key dimension relevant to science identity formation, while further reinforcing the idea that such recognition can be complicated by interactions with racial, ethnic, and gender identities (Carlone, Haun-Frank & Webb, 2011; Carlone, Scott & Lowder, 2014; Wong, 2012). Specifically, whether or not students view science as being for people “like them” appears to be an important factor that influences their science identity development and career aspirations (Archer et al., 2012; Archer et al., 2013; Wong, 2012). Such beliefs are likely influenced in part by popular images of who scientists are and what they do. In fact, studies with young people spanning three decades have demonstrated that the enduring prototypical image of a scientist remains a lone white male with a labcoat, glasses, and facial hair, holding laboratory equipment (Author, Chapter 3; Barman, 1997; Chambers, 1983; Reveles, 2009). In addition, more recent research has revealed the ways in which cultural discourses around science (e.g., science as masculine) can render aspirations for careers in science “unthinkable” for many young women, especially those from working class or ethnic minority backgrounds (Archer et al., 2013; Wong, 2012). Thus lack of congruence between such popular images and discourses and adolescents’ beliefs about themselves may limit their ability to recognize advanced science coursework and careers as viable options for people “like them.”

Motivational factors, such as believing that science is interesting, important, or relevant to future career plans, also appear to influence adolescents’ science identity

development (Archer et al., 2012; Archer et al., 2013; Archer et al., 2010). Such beliefs can help motivate students to develop competence in science-specific ways of reasoning and communicating, which can differ markedly from everyday reasoning and language (Gee, 2004). Like the earlier discussed dimension, students' interest in science and beliefs about its importance can suffer when popular discourses about science and scientists represent limited and noninclusive views (Archer et al., 2012; Archer et al., 2013).

Therefore, drawing on the aforementioned research, I focused on two major dimensions related to students' science identity development in order to operationalize it for the purposes of this article. The first dimension, *believing that science is accessible to people "like me,"* builds on previous research on the importance of recognition of self as a science person. The second dimension, *believing that science is interesting or important,* builds on previous research on the importance of motivation.

What is known about Adolescents, their Attitudes toward Science, and Science Identity Development?

Recently, Project ASPIRES, based at King's College London, conducted a multi-year mixed methods investigation of science attitudes and career aspirations among a nationally representative sample of 10-14 year olds across England. In total, this project collected data via 19,000 student surveys administered at three time periods and repeated longitudinal interviews with a subsample of 83 students and 65 of their parents (ASPIRES, 2013). Results indicated that students generally had positive views of school science and scientists, but very few were interested in science as a career. Moreover, the

vast majority of surveyed students agreed that scientists are “brainy” and this image seemed to play a role in convincing many that science is not for people like them.

In addition to these overall trends, differences were observed from a young age across students of different genders, ethnicities, and economic backgrounds. For example, the students who were most likely to express interest in science careers were Asian males, who were from families with high levels of cultural capital, had been tracked into the highest ability group in science, and had a family member working in a STEM-related job. In contrast, the students least likely to express interest in science careers were White females, who were from families with low levels of cultural capital, had been tracked into the lowest ability group in science, and did not have any family members with STEM-related jobs. Moreover, females who defined themselves as “girly” were particularly unlikely to express interest in a STEM-related career, which did not appear to be compatible with their constructions of femininity (ASPIRES, 2013; Archer et al, 2013). This perceived lack of congruence appeared to be particularly salient among girls from working class families (ASPIRES, 2013; Archer et al, 2013).

What shapes students’ science identity? Students draw from many sources in constructing (or rejecting) science identities. Studies attending to classroom language have demonstrated how science teachers’ language—and their use of personal pronouns in particular—can position their students as members of scientific communities (Moje, 1995; Author, Chapter 3). For example, Moje (1995) described a high school chemistry teacher who responded to her student’s statement that “actual yield” might be “what the chemists get” by saying, “Yes. It’s what *you* get. You’re a chemist, too. You’ll get an actual yield in the lab” (Moje, 1995, p. 364). However, not all messages about what

science is and who it is for are this explicit in nature. Other studies have revealed how school science is often taught in ways that indicate that it is only meant for the “superintelligent elite” (Lemke, 1990, p. 160), favor the participation of male students over female (For a review of this research, see Guzzetti, 2004), or create disaffiliation with being a “science person” among certain students, especially girls and students from some ethnic minorities (Carlone, Haun-Frank, & Webb, 2011; Carlone, Scott, & Lowder, 2014).

Factors beyond school also play a role in shaping students’ science identity. Adolescents’ family members and cultural discourses also affect their views of who scientists are, what they do, and whether science is for people like them. For example, Project ASPIRES highlighted the importance of “science capital,” defined as a family’s “science-related qualifications, understanding, knowledge (about science and ‘how it works’), interest and social contacts (e.g. knowing someone who works in a science-related job)” (ASPIRES, 2013, p. 3). Such science-capital tends to be unevenly distributed such that it is more available among students from middle-class families than students from working class families (ASPIRES, 2013). In addition, as noted earlier, popular images and discourses around science and scientists also shape the young people’s views (ASPIRES, 2013; Archer et al, 2013; Wong, 2012).

What is the Relationship between Science Identity and Science Knowledge?

There is limited research exploring the relationship between students’ science knowledge and their science identities. However, research drawing from the anthropological and sociological traditions suggests that science identity and science knowledge should be viewed as related but distinct constructs (Brickhouse, Lowery, &

Schultz, 2000; Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Kanter & Konstantopoulos, 2010; Wong, 2012). In particular, this research indicates that students who demonstrate knowledge in school science classes do not always view science as relevant to their lives or being for people like them. Furthermore, evidence from intervention work indicates that students can gain science knowledge without building stronger science identities. Specifically, Kanter and Konstantopoulos (2010) found that implementing a project-based science curriculum in urban schools increased the science achievement of middle graders from ethnically and racially underrepresented groups, but did not improve their attitudes toward science or increase their plans to pursue science. While more research is needed, it is plausible that helping girls, and especially girls of color, to strengthen both their science knowledge *and* their science identities is necessary to impact longer-term outcomes such as taking college science courses or choosing a science-related profession. All-girls schools, which eliminate the male-dominated participation patterns found in many coeducational science classrooms (Guzzetti, 2004), might provide a favorable environment for undertaking such work.

As this brief review illustrates, there is a growing body of research demonstrating that science identity is an important factor in explaining science engagement and achievement among adolescents. However, there are several important areas in need of investigation. First, little is known about how adolescents in different classroom contexts are socialized into different ways of constructing science identities. Specifically, although it is not uncommon for proposals designed to address the underrepresentation of women in science to call for single-gender science classrooms, little empirical work has been conducted in these settings. To my knowledge, no studies have examined the science

attitudes and constructions of science identity among girls attending such a school where the teacher used language and instructional practices that actively encouraged her students to view themselves as scientists and construct a more inclusive view of who scientists are and what they do. In addition, there is a relative lack of empirical work that has attempted to systematically examine multiple dimensions related to science identity using both quantitative and qualitative measures. As a first step in addressing these unanswered questions, I report here on the results of a 7-month study of students' science identity conducted in one small all-female school serving ethnically and linguistically diverse students, primarily from working class homes.

Study Design and Methods

As noted previously, the data I analyzed for this article were drawn from a larger study of science literacy at the Lyon Academy. The overall study employed a multiple-case embedded study design (Yin, 2009), which allowed cross-case comparisons at the classroom and student levels. The embedded design was chosen because my overall research goals involved two units of analysis: the classroom and the individual student. However, in this article I focus on student-level data to explore the Lyon Academy students' attitudes toward science and constructions of science identity.

School and Classroom Context

The study was conducted in Ms. Marsh's four science classes (grades 5-8) at the Lyon Academy, located in a mid-size city in New England. According to US census data, in 2010 approximately 38% of the city population was Latino with a similar percentage of non-Latino White residents. The city was also home to smaller numbers of Black, Asian, American Indian/Alaska Native, and Multi-Racial residents. Almost half of

residents over the age of 5 came from a home where a language other than English was spoken. Additionally, approximately 28% of residents were living below the poverty level.

The Lyon Academy was founded in 2000 to serve adolescent females, primarily from the city's working class households. The school's purpose was to offer girls facing economic hardship an "empowering educational program" focused on their intellectual and emotional growth. At the time of data collection, the school had a total enrollment of 55 students in grades 5 through 8, most of whom (94%) came from families eligible for free or reduced price lunch. Mirroring city demographics, roughly half of Lyon Academy students came from a home where a language other than English was spoken. However, Latina (62%) and Black (26%) students were more heavily represented at the school than in the overall population of the city. The remaining students were identified as multi-racial (8%), Asian (2%) and White (2%). Despite these demographics, at the time of data collection, students at the Lyon Academy had outscored their citywide peers on the New England Common Assessment Program (NECAP) test for several years. Additionally, over 90% of Lyon Academy alumnae continued on to graduate from high school four years after leaving, and close to 100% did so within five years.

Because of the Lyon Academy's limited enrollment, there was only one teacher for each content area. For this reason, the school used a two-year (A/B) science curriculum cycle. The content taught changed between A and B years, but each year's 5th and 6th grade cohorts learned the same content. Similarly, the 7th and 8th grade cohorts shared science content. During the data collection year, 5th and 6th grade students studied Life Science with units on Environments, Microworlds, and Land and Water. The

7th and 8th grade students studied an Earth Science unit on Weather and Water and a Life Science Unit on Populations and Ecosystems. Science instruction often involved hands-on activities, although more traditional activities such as reading from textbooks and taking notes also occurred in the Lyon Academy classrooms. As noted earlier, during instruction Ms. Marsh positioned her students as working scientists and encouraged them to see the relevance of science to their lives beyond the curriculum.

Participants

Students. I invited all 55 Lyon Academy students in grades 5-8 to participate in the classroom observation and survey portions of the study. Fifty students consented to participate. In addition, I interviewed a subsample of 12 students (three from each grade). I selected these students to represent a range of teacher-identified science achievement levels at each grade. In this article, I present data from three case study students selected from the subsample of 12. These three students are (a) Effie, a high-achieving, Black 6th grader, who was born in Cameroon and speaks mainly English and some French at home (b) Mandy, a high-achieving, US-born, Multi-Racial 5th grader, who speaks only English at home, and (c) Gloria, a low-achieving, US-born, Latina 6th grader who speaks Spanish and English at home. I selected these students because they represent the variation in the sample in Lyon Academy students' attitudes toward science and constructions of science identity. In Table 1, I summarize select demographic, science attitude, and career aspiration data for these three students.

Teacher. Ms. Marsh, the science teacher at the Lyon Academy, is a White female with a Master of Arts in Teaching degree from an elite private university. At the time of

data collection, she was 31 years old and in her 5th year teaching and her 4th year at the Lyon Academy.

Data Collection Methods and Procedures

I collected the data for this study over a 7-month period (October through April) during a single academic year. The central data sources for this article were (a) a student survey administered to all participating Lyon Academy students and (b) interviews with three case study students. I describe both of these data sources in more detail below. In addition, I triangulated the survey and interview data with data from fieldnotes (Emerson, Fretz & Shaw, 2011) and videorecorded classroom observations (102 classes, 113 hours, recorded on 29 days).

Surveys. In January of the data collection year, all participating students completed a pencil and paper researcher-designed survey during a single science class period. The overall survey consisted of 45 items designed to document students' attitudes toward science, and beliefs about constructing knowledge in science and reading and writing in science. The analyses presented in this paper focus on ten survey items from the attitudes toward science portion of the survey. Five of these items asked about students' beliefs about the *accessibility of science to "people like them"* (e.g., How often are people like you who want to be scientists able to become scientists?). Another five items asked about students' *interest in science and beliefs about its importance* (e.g., How helpful is learning science to meeting your goals for yourself?)⁵. All responses were

⁵ I designed this survey to reflect two underlying substantive dimensions: (a.) students' beliefs about the accessibility of science to people "like them" and (b.) students' interest in science and beliefs about its importance. These dimensions have not been empirically validated. I considered using exploratory factor analysis as a data reduction technique and source of validation for these constructs. However, such analysis is problematic because of the low ratio of observations to variables in my data and the existing evidence that exploratory factor analysis is not sufficiently sensitive for determining dimensionality (Koretz,

recorded on a 5-point Likert-type scale. Following best practices in survey design, response scale anchors mirrored the construct-specific language in the questions (Dillman, Smyth, & Christian, 2009).

Semi-Structured Interviews. In April of the data collection year, I conducted semi-structured interviews with a subsample of 12 focal students. Interviews were conducted one-on-one in an empty office or classroom and ranged in length from 18 to 37 minutes. The interview protocol included questions about students' future career plans and a range of topics related to science literacy. The analyses presented in this paper focus on the questions most relevant to understanding the students' constructions of science identity. Thus my analyses concentrate on the portions of the interview where students talked about (a) their attitudes toward science, including whether they like it and whether they ever use things they learn in science class outside of school, (b) a description of an imagined scientist at work, (c) what types of people usually become scientists, and (d) an image of themselves in science class.

Researcher Stance

Throughout my interactions with Lyon Academy students, I tried to present myself as a curious adult friend, rather than a teacher. At the beginning of data collection, I explicitly told students that I believed that they were the best experts on their own learning and that I wanted to learn from watching them and listening to what they had to say. I wished to be seen as a regular nonjudgmental presence in the classroom. Therefore, I did not instruct students, nor did I discipline them for the minor infractions in school rules that I observed (e.g., voices too loud when teacher stepped out of the room). As a

personal communication). The underlying structure of survey should be examined at a later date with a larger student sample.

mark of my distinct status, the students called me by my first name, “Beth,” rather than “Miss Faller,” which was how they addressed their teachers. During classroom observations, students appeared to be comfortable joking and engaging in nonacademic talk with peers while I was around. Likewise, during interviews students appeared to be comfortable telling me things they didn’t like about science class.

Data Analysis

I used quantitative and qualitative analysis techniques to explore Lyon Academy students’ attitudes toward science and constructions of science identity. First, I calculated descriptive statistics for the survey data. Since the survey is not on an interval scale, I determined the median and interquartile range (IQR), measures of central tendency and dispersion respectively, for each item. Next, after data collection was complete, I transcribed the full student interviews and coded them using an inductive open coding approach (Charmaz, 2006; Maxwell, 2005; Corbin & Strauss, 2008) in Atlas.ti qualitative analysis software. The interviews presented in this article were initially coded as part of a larger study that examined Ms. Marsh’s language and instructional practices and patterns in the construction of science identity among all 12 interviewed students (See Chapter 3). The initial coding I used for Chapter 3 focused on student perspectives on (a) who scientists are and what they do, and (b) whether science is useful or relevant to their lives. However, during this analysis, it became clear to me that each of the interviewed students had a unique perspective that was not fully captured within this coding scheme. While coding broad patterns across all 12 interviews allowed me to answer my initial research questions, it did not allow for an in-depth analysis of individual students’ experiences, attitudes, and constructions of science identity. Thus I selected three case study students

who presented contrasting perspectives for the in-depth analysis that I present in this article.

To understand the unique perspectives of each case study student, I returned to the full interviews for the three students and reread each as a whole. I then crafted narrative profiles (Seidman, 1998) for each student in order to compare and contrast experiences, attitudes, and images of scientists across the three students. For the profiles, I used the students own words whenever possible. I used these profiles as a starting point for examining each case study student's perspective and identifying emergent themes. For example, the theme of *doing science as active vs. passive* emerged at this point. I then revisited the full transcripts for the case study students to review and refine the emergent themes. I triangulated interview data for the three case study students with their individual survey responses and observational data. Throughout data analysis, I engaged in a process of writing analytic memos, building theories, and returning to the data to verify, reject, and refine these theories.

Findings

In the following sections, I first report on my analysis of survey data from all Lyon Academy students. I then use this overall analysis as a backdrop for discussing the attitudes and experiences of three case study students, Effie, Mandy, and Gloria. These case studies allow me to explore three students' attitudes toward science and science identity constructions in depth and help to explain some of the overall survey findings. Taken as a whole, these analyses illustrate the differences in attitudes toward science and constructions of science identity found even among students in the same supportive all-girls educational context.

Overall Science Attitudes Survey Results

Accessibility of science. In spite of a supportive classroom environment where their teacher encouraged them to view themselves as scientists, many Lyon Academy students reported reservations about whether the profession of science was open to people “like them” (Table 2). For example, the typical Lyon Academy student reported that it is only *somewhat easy* for people like her to become scientists ($Mdn=3$, $IQR=2-3$) and that people like her who want to be scientists are only *sometimes able* to become scientists ($Mdn=3$, $IQR=2-3$). Moreover, the typical Lyon Academy student indicated that science is *very difficult* ($Mdn=4$, $IQR=4-4$) and that things she cannot control get in the way of her understanding science *most of the time* ($Mdn=4$, $IQR=3-4$). Surprisingly, given these results, most Lyon Academy students reported that you only have to be *a little smart* ($N=17$, 34%) or *about as smart as most people* ($N=21$, 42%) to be a scientist ($Mdn=2$, $IQR=2-3$).

Interest in and importance of science. In contrast to their somewhat ambivalent views about the accessibility of science, many Lyon Academy students reported a high level of interest in science (Table 2). For example, the typical student indicated that she thinks science is *very interesting* ($Mdn=4$, $IQR=3-4$) and *very useful* ($Mdn=4$, $IQR=3-4$). However, responses were more divided when the students reported on the importance of science for specific situations and goals. For example, the typical student reported that learning science was only *somewhat important* for her future ($Mdn=3$, $IQR=3-4$). Moreover, there was little consensus with regard to the applicability of science beyond school. Many of the Lyon Academy students ($N=16$, 32%) reported that learning science was *very* or *extremely helpful* for meeting their future goals for themselves, while a

similar number ($N=14$, 28%) indicated that it was *a little helpful* or *not helpful at all* ($Mdn=3$, $IQR=2-4$). Similarly many of the students ($N=17$, 34%) said that they use things they learn in science class outside of school *most of the time* or *almost all the time*, while a slightly greater number ($N=23$, 46%) indicated they did this *once in a while* or *never* ($Mdn=3$, $IQR=2-4$).

Three Case Studies: Effie, Mandy, and Gloria

The overall analyses of survey data from all Lyon Academy students revealed an intriguing pattern, a general consensus that science is interesting, coupled with more ambivalence about its usefulness for particular situations and its accessibility to people “like them.” With these overall analyses as a backdrop, in this section I present analyses of data from three contrasting case study students, Effie, Mandy, and Gloria (See Figures 1 and 2 for a comparison of survey results for these three students.) In the following sections, I first provide a brief introduction to the three students to situate my analyses, which are organized according to two themes: (a.) What is doing science and does it matter outside of school? and (b.) Who does science?

Introduction to the case study students.

Effie. Sixth grader Effie’s family emigrated from Cameroon when she was 5 years old. At home, her family usually spoke English, although they also used some French. Effie was one of many Lyon Academy students with other family members who also attended the school. Ms. Marsh taught Effie’s older sister a few years prior to data collection for this study. Like her sister, Effie was an enthusiastic science student whom Ms. Marsh identified as above average in achievement. Effie also believed that she was “good at science” and appeared to take pride in her science achievement, which she

described by referring to her own learning as well as external validations of her knowledge. For example, when I asked her how she knew she was good at science, Effie said, “I can tell I’m good at science because of the way I understand the things that Miss Marsh talks about and how I interact with other [living] things [during experiments] and my grades.” Although new to the Lyon Academy as a 6th grader, Effie seemed to fit in well with her peers and to enjoy science class, which she described as “fun.” During my classroom observations, Effie frequently asked and answered questions, making connections to experiences from beyond the Lyon Academy such as a science experiment she had done at a prior school. In her survey responses, Effie tended to respond in a similar manner to or more positively than the median Lyon Academy student for questions about the accessibility of science, although she did indicate that it was only “a little easy” for people like her to become scientists. She consistently responded in a similar manner to or more positively than the typical Lyon Academy student for questions related to how interesting and useful learning science is.

Mandy. Fifth grader Mandy was born in the United States into a multi-ethnic family, which school records classified as Black and White. Her family was one of three Lyon Academy families not eligible for free or reduced price lunch and spoke only English at home. Mandy was an enthusiastic science student whom Ms. Marsh identified as above average in achievement. Mandy agreed that she was “pretty good” at science. Like Effie, she referred to both her own knowledge and external validation in explaining why she thought she was good at science: “I usually know stuff and I usually get pretty good grades on the test.” During observations, Mandy seemed to enjoy participating in hands-on experiments in science class, although she would often doodle in her notebook

during more traditional activities such as note-taking. It was not uncommon for Ms. Marsh to repeat instructions or otherwise check in with her to see that she remained on task. Still, Mandy was a regular contributor when Ms. Marsh asked questions and was quick to use newly-introduced technical terms, such as *photosynthesis* and *optimum condition*. In her survey responses, Mandy consistently responded in a similar manner to or more positively than the median Lyon Academy student for questions about the accessibility of science. However, she often responded more negatively than the typical Lyon Academy student for questions related to how interesting and useful learning science is.

Gloria. Gloria was a Latina 6th grader who was born in the United States. Her family spoke both Spanish and English at home. Gloria did not label herself as someone who is good at science and Ms. Marsh described her as below average in science achievement. During classroom observations, she sometimes participated by answering Ms. Marsh's questions, manipulating tools, and discussing work with other students, but at other times, she sighed, sat quietly or put her head down on the table. In general, her survey responses related to both accessibility and interest were less positive than the typical Lyon Academy student.

What is doing science and does it matter outside of school? Ms. Marsh's classroom provided an important source for the Lyon Academy students to draw on in developing their attitudes toward science, including their beliefs about what constitutes doing science and whether science is relevant to their lives beyond school. Perhaps not surprisingly, each case study student's discussion of doing science was heavily influenced by her interpretation of the experiences she had had in Ms. Marsh's

classroom. What is more surprising is that in spite of attending science classes taught by the same teacher and using the same curriculum, there were striking differences across the students in whether their descriptions indicated that doing science was an active or passive process and how they described reacting when they did not immediately understand something in science.

Effie: Science as putting it all together and figuring it out. Effie's discussion was notable for its depiction of doing science, at least as enacted in Ms. Marsh's classroom, as a remarkably active process. She presented a vision of science that required both hands-on physical activity and mental activity. Like the other case study students, when I asked Effie if she liked science, she focused on her classroom experiences:

Beth: Do you like science?

Effie: Yeah.

Beth: OK. Why do you like it?

Effie: I like it because it's fun and I get to learn new things every day and I like how Miss Marsh teaches it because she makes us like, if we don't understand it, she'll try to answer it, but try to make us answer it instead of her having to answer it 'cause she knows that we know the little details to figure it out. So she's gonna try to make us put it all together and figure it out on our own.

Beth: And so you like that better than if she just told you?

Effie: Yeah, because if she just told me, then I haven't really learned anything. I just got information that I don't understand.

Beth: OK. And you said it was fun. What's fun about it?

Effie: It's fun how we have hands on things and we get to play with new equipment and different types of organisms.

As illustrated by this exchange, Effie linked her liking of science with the challenge it posed. While she indicated that students do not always immediately “understand” things in science, they can arrive at understanding through engaging in a process involving both physical activity (“hands on,” “play with new equipment”) and mental activity (“put it all together and figure it out”). In addition, Effie claimed that Ms. Marsh encouraged her students to actively participate in constructing new knowledge. That is, by positioning her students as competent and capable of doing science (“she knows that we know the little details”), Ms Marsh allowed her students to rise to the occasion, figuring things out “on our own” and arriving at a deeper understanding. Effie contrasts this active vision of science as “figuring out” with a vision of science (or at least school science) as passively receiving information. In the passive information-receiving scenario there does not appear to be a way for students to construct new knowledge from the facts they are told if they do not immediately understand (“I just got information that I don't understand.”)

Effie's active vision of science, which emphasized “figuring things out” and “understanding,” also led her to endorse collaborating with other people representing multiple perspectives, something she said she did in Ms. Marsh's classroom:

Beth: And do you think that's important, to work with someone else, to science, or not really?

Effie: I think it is, because if you have one perspective, then you won't really look at everything. You'll look at one thing. But if you have

more than one pair of eyes on it, then you have more people understanding it and more people seeing things that you don't see.

In the previous quotation, it is notable that Effie connects collaboration and the availability of multiple perspectives with developing deeper understanding in science.

Effie clearly endorsed the active vision of doing science she associated with Ms. Marsh's classrooms, but her interest in science was not confined to the classroom. She also talked about how what she learned in science class could be readily applied to her more general understanding of the world around her:

Beth: And do you ever use things you learn in science class outside of school?

Effie: I use the, because now in this unit we're learning about microscopes and microorganisms, now I go home and I think about what I can't see and how much different things are around me that I can't see and I try to figure them out and stuff.

As this quotation illustrates, Effie indicated that she applies what she learns in the science classroom to try to better understand her world. Notably, in making this connection, she again used the phrase "figure out," this time applied to using something she learned in her science classroom to understand the world beyond the classroom.

Mandy: Science as doing cool stuff. Mandy's description depicted doing science as something that requires a lot of "fun" hands-on physical activity. However, it was not entirely clear what she believed the purpose of the hands-on activity to be and her description did not allude to engaging the mind as well as the hands. Like Effie, Mandy

drew on her experiences in Ms. Marsh's classroom in order to answer the question of whether she liked science:

Beth: So do you like science?

Mandy: Yeah. I like science.

Beth: OK. Why do you like it?

Mandy: Because we get to do a lot of cool stuff and look at stuff under the microscopes.

Beth: OK. So what would be cool about something you'd be doing?
Like what makes it cool?

Mandy: If I'm looking, like we were looking at the vinegar worm, vinegar eels and they looked really cool under the microscope because there were a lot of them and they were all wiggling around.

As illustrated by the above quotation, Mandy expressed a positive orientation toward science. However, this enthusiasm was mainly centered on hands-on activities, such as manipulating equipment, and seeing "cool" things that might "surprise" or "interest" her. Her focus on the "fun" hands-on aspects of science did not make it clear whether or how engaged she was in connecting these hands-on activities to scientific ways of reasoning or larger concepts in science.

Consistent with this view of science as doing cool hands-on activities, Mandy indicated that collaborating with other people was peripheral to the work of science. In discussing partner work in Ms. Marsh's classroom, Mandy described two people doing hands on-activities independently but in parallel and then sharing their observations:

- Beth: And are you working with anyone else or you working by yourself?
- Mandy: My partner is also looking at a microscope but I do my own observations.
- Beth: OK.
- Mandy: But my partner is there. They're looking through their microscope.
- Beth: And then would you ever do anything with your partner or would you mainly be just doing your own thing?
- Mandy: Sometimes we do thing, we do things with our partner a lot, but when we're just looking at stuff, we mostly just look at the stuff on our own. Then we share with our partner.
- Beth: OK. And is it important to work with someone else in science, or not really?
- Mandy: It can be. It can be important. Me personally, sometimes I don't really like working with people 'cause that's just the kind of way I am.
- Beth: Umm hmm.
- Mandy: But sometimes I do like working with people.
- Beth: So is that true of other classes too? That's not about science? You just tend to like to work on your own?
- Mandy: Umm hmm.

Beth: Yeah. And when you do like working with someone else, what makes you like it?

Mandy: What makes me like it is that you can have fun with another person and they help you on stuff, and stuff.

Although her perception of group work seems to be at least partially driven by her stated personal preference to work alone (“that’s just kind of the way I am”), Mandy did not indicate that working with others is central to the discipline of science. In fact, even her description of what might be positive aspects of working with others focused on tangential benefits (“you can have fun with another person”) rather than any potential benefits to learning or knowledge construction.

Mandy’s focus on the novel and surprising aspects of doing hands-on science, such as interesting organisms or apparatus, made it difficult for her to make a clear connection between science class and her life beyond school. Consistent with her survey responses, she indicated little relevance of science to her life beyond the classroom:

Beth: And do you ever use the things you learn in science class outside of school?

Mandy: Not that much but sometimes.

Beth: OK. What would be an example of when you might use it?

Mandy: Like if my cousin is saying something or something and then I correct him.

Beth: So has that happened before?

Mandy: Yeah.

Beth: Your cousin had said something and then you corrected him?

Mandy: Umm hmm.

Beth: Do you remember what you corrected him on?

Mandy: Uh, no.

Thus, while Mandy seemed to believe in her own competence in science and talked about the hands-on activities in class as “fun,” “interesting,” and “cool,” focusing on the hands-on activities gave her little room to make connections to the broader world. When doing science is conceived of as completing assigned hands-on activities rather than developing new ways of reasoning and understanding the world, it is not surprising that science would seem to have little relevance to life outside of school. Interestingly, Mandy’s example of when she might use something she learned in science involved providing her cousin with correct information (“then I correct him”), rather than a more active process of trying to come to a new understanding.

Gloria: Science as doing what’s expected of you. Gloria’s description of doing science was notable for its passivity. She presented a vision of science where success comes from doing what is expected of you and following directions. For Gloria, avoiding trouble seemed to be more important than arriving at understanding. Consistent with this passive vision of science, Gloria provided a strikingly disengaged image when I asked her to describe herself in science class:

Gloria: OK. So I’m in the science room, like the one upstairs. And nobody’s in the room with me and I’m just sitting down, staring at the table.

Beth: OK. And so nobody’s around you. So, why are you all by yourself, do you think?

Gloria: 'Cause I yell at a lot. I yell at a lot of people. Like if I get frustrated, I'll yell, and that's why I'm staying at the table.

Beth: Because you're frustrated?

Gloria: [nods]

Beth: And what makes you frustrated about science?

Gloria: I don't get it sometimes.

Beth: Like you don't understand it?

Gloria: Yeah.

Gloria's vision of doing science in Ms. Marsh's room involved both physical passivity ("sitting down," "staying at the table") and mental passivity ("staring at the table," "I don't get it"). For Gloria, this passivity seemed to be a (slightly) better alternative to acting out when she doesn't understand something ("if I get frustrated, I'll yell").

Importantly, she did not seem to believe that she had any productive options for actively constructing knowledge when she did not immediately understand something in science class and so she described reacting with anger or passivity.

The themes of "getting frustrated" and "not getting it" ran throughout Gloria's discussion of science. She referenced her lack of understanding as getting in the way of both liking science and being good at it. For example, she talked about science not as something she *was* good at, but as something she *could* be good at if she understood it:

Beth: Do you think you're good at science?

Gloria: Well, I think I am good at science and I could be good at science, that if I understood it more. Like sometimes when I get something

I'm like I don't understand it, but then most people assume that I wasn't listening. So, that's why I usually don't ask questions.

Beth: Because you're afraid that if you ask questions, that people'll assume you weren't listening?

Gloria: Yeah.

Beth: And really it's that you sort of have looked at it and just still don't understand it?

Gloria: [nods]

As this exchange illustrates, Gloria talked about science as something where understanding should be immediate and immediately demonstrable. A good science student should know the answers right away and be able to provide them in order to receive recognition. Thus, when she did not understand something, the best course of action appeared to be to remain quiet to avoid possible censure ("most people assume that I wasn't listening").

In addition, Gloria's passivity in science class seemed to be influenced by a belief that compliance and doing what one is told are the best ways to do well:

Beth: What makes somebody a good scientist?

Gloria: To listen and go back to, like Miss Marsh says, go back to your work and check it and that's why you have data on stuff and stuff like that.

Beth: OK. So to go back and check it and you said to listen. Anything else you should do to be a good scientist?

- Gloria: I don't know. It's like everything you gotta do, like everything that's expected from you. You should do it if, for to be a scientist.
- Beth: OK. And how would you, like how do you find out what's expected of you?
- Gloria: Somebody will tell you and then you probably know because you went to a school or something that tells you this is what scientists need, like to write everything down, write the date, observe, you know, like yeah.
- Beth: OK. So, it would be sorta the things your teachers told you in school, maybe?
- Gloria: Yeah.

In this exchange, Gloria clearly associated being a good scientist, the language I used in my original question, with doing what one is told ("somebody will tell you"). This orientation toward compliance was also present when I asked Gloria how she would know for sure that something was a science experiment. She responded, "If there was a book right there that said that you should do that." Gloria's comments were reminiscent of the view of science promoted in many classrooms that privilege memorizing information and following procedures to arrive at expected results. Such an orientation toward compliance with a behavior regardless of whether one understands the underlying rationale might help to explain Gloria's frustration with science. Not surprisingly, given her passive version of doing science, Gloria said she never once used anything she learned in science class outside of school.

Who does science? In addition to their views on what it means to do science, I was interested in learning about the case study students' perceptions of whether science was open to anyone who wished to pursue it or whether there were external barriers that might limit their access. The most striking aspect of these discussions is that while all three students indicated that attributes that anyone can develop are key determinants in who becomes a scientist, both Mandy and Gloria drew to some degree on noninclusive popular images when they described an imagined scientist.

Effie: It doesn't really matter what type of person you are. Effie indicated that attributes that anyone can develop, rather than fixed traits, are the most important factors in determining who will become a scientist. In particular, she focused on liking science and being committed to it in the long term:

Beth: Is there a certain type of person who usually becomes a scientist?

Effie: I think it kinda depends. If you really like science and you really like what you're learning about, then it doesn't really matter what type of person you are.

Beth: OK.

Effie: So, yeah.

Beth: So, the most important thing is liking it?

Effie: Yeah.

Beth: Is anything else important to becoming a scientist?

Effie: You have to know what you're dealing with and you have to know what you're putting your mind up to 'cause when you're

doing science you can't just decide one day you don't want to do it anymore. You have to be committed to it for a long, long time.

Beth: OK. And do you think that's different than other things?

Effie: Yes. Because when you're doing some other thing, it doesn't take as long to do it, because to be a scientist you have to be prepared to study one thing for a long time and then when you get to one point that you really understand it, you move on to another thing.

As this exchange illustrates, Effie emphasized the related aspects of “really liking” science and being committed to it. These attributes seem to link to her earlier discussed conception of science as “figuring things out.” For Effie, developing this type of knowledge seemed to require persistence and “putting your mind to” something for a “long, long time” in order to get to the “point that you really understand” it.

Consistent with Effie's view of science as an active process that is open to all types of people who are willing to commit to it, when I asked her to picture a scientist in her mind and then tell me about the image, Effie's description contained none of the elements signaling a limited and noninclusive view of scientists often found in young people's descriptions:

I forgot her name but she's a scientist and she works with animals and monkeys and she would probably be outside in Africa...I learned about her in my old school when we were studying the scientists in third grade. So I don't remember her name, but we were studying different types of science that you could be learning and we studied about that. Yeah [it's Jane Goodall]. She's probably playing with the monkeys or chimpanzees and trying to understand and writing

down notes, what they're doing and how they breed or how they clean each other...I don't know [if she works with other people], but she probably works with other scientists who work with other animals to try and figure out what's the same and what's different about this animal and another animal.

Here, Effie described an image of a scientist that contradicted many more limited and noninclusive popular images. Rather than the lone male in a lab with chemicals, Effie's scientist was a woman who worked with other scientists and was out in the world observing animal behavior. Consistent with her earlier comments about science, in Effie's image Goodall is active, both physically ("playing with monkeys") and mentally ("trying to understand"). Interestingly, in this description, Effie referred to having learned about "different types of science," indicating that her view of who scientists are and what they do might be expansive enough to include a wide array of people and activities.

Mandy: Some scientists work in a lab and some go out. Mandy also presented a view of science where interest was the most important characteristic in determining who would become a scientist. However, in her description, Mandy emphasized that such interest could develop over time:

Beth: And is there a certain type of person who usually becomes a scientist?

Mandy: I think that usually a person who really likes science becomes a scientist, but even if you don't like science when you're a kid, you could become to like it when you grow up.

This developmental perspective was again evident when I asked Mandy to elaborate on a statement she made that scientists have to be smart:

Beth: And then you said they have to be smart. Do they have to be sort of average smart or do they have to be really smart?

Mandy: Well, you kind of get smarter by how much you learn, so [...] they would have to have learned things and stuff.

As illustrated by these quotations, Mandy's developmental perspective seemed to indicate that anyone can become a scientist as long as they develop interest and knowledge at some point.

Interestingly, when she imagined a scientist, Mandy described two images: one influenced by the inclusive view of science discussed above and one that drew much more heavily on more limited and noninclusive features found in many young people's images of scientists:

Some scientists work in a lab, and some go out, they go outside and to different places and they try to find out new stuff about the world. I see [a scientist] holding a test tube or something. Or digging. The scientist who's digging is a woman. She has long brown hair, and the scientist who's in the lab is a man. The scientist in the lab is wearing a lab coat and the scientist who's digging is wearing just like jeans and a shirt. No [they're not working with anybody else, but they do work with other people] a lot of the time, especially that one that's digging. They would go together out and dig together and see what they find and they all work together to find out the information. They would work together to analyze information and find new stuff.

Here Mandy's two scientists almost seemed to be vying for dominance as she moved back and forth from one to the other in her description. Mandy drew almost equally from

both an archetypal scientist—a lone male scientist in a lab with a lab coat and test tube—and a more inclusive view—a female scientist in jeans out digging and working with a team. Notably, she drew on the more limited view when she described a scientist in the physical sciences and the more inclusive view when she described an archeologist, perhaps indicating different views of who participates in the different sub-fields of science.

Gloria: He's not dark skinned. Gloria also endorsed the view that an attribute that anyone can develop is the most important determinant of who will become a scientist. However, as will be discussed shortly, she contradicted this idea in describing her image of a scientist. Still, when asked about the type of person who usually becomes a scientist, Gloria indicated that effort was key:

Beth: Is there a certain type of person who usually becomes a scientist?

Gloria: What do you mean?

Beth: Are all people equally likely to become scientists or are some people more likely than others?

Gloria: Depends if they try hard.

Beth: OK. So the main thing is how hard they try?

Gloria: [nods]

Interestingly, as discussed previously, Gloria's conception of "trying hard" in science was bound up with the idea of doing what you are told to do.

Despite her initial discussion of scientist as a profession open to anyone who tries hard, Gloria's description of an imagined scientist was heavily reliant on limited and noninclusive popular images:

Something that I'm thinking about is that they're in a white room. And it's kind of like the tables that we have in science [class]. They're all black and then they have them science tubes, like the tubes that they use to pour like, I don't know how to call it, like acids and other thing, like liquid into another liquid to make a experiment. [The scientist is] a man with a beard. He's not dark skinned. I never seen a dark skinned person doing science that much. So that's why. [He's wearing] a lab coat. [He's] alone. He's frustrated cause he's by himself but he's very rude. It's like I'm making a story, but I just see him multitasking, like going to each table, try to do different things, different experiments. There's a station at each table, like one station's for experiments, one's dissecting something, one's taking notes. [He's doing] something for NASA.

In her description, Gloria drew heavily on generic noninclusive popular images, which were sometimes devoid of real meaning (e.g., pouring a liquid in a test tube into another liquid without a clear reason for doing this). Interestingly, Gloria was the only student to attribute negative emotions (“frustrated”) and social behaviors (“very rude”) to her imagined scientist. In addition, Gloria's explanation of why her scientist is “not dark skinned” seemed to make a distinction between what happens in Ms. Marsh's classroom, where Ms. Marsh positions her female students of all skin tones as scientists doing science, and truly doing science (“I never seen a dark skinned person doing science that much.”)

Discussion

In the face of the continued underrepresentation of women in almost all science and engineering fields and concerns about the nation's prospects of remaining

competitive in science and technology (Hill, Corbett, & St. Rose, 2010), there is a need to focus on the ways in which adolescent girls construct science identity—that is, their beliefs about who scientists are, what it means to do science, and whether science is interesting or important. This focus on science identity is warranted since girls’ science achievement alone does not seem to predict whether they will pursue advanced science coursework or science-related professions (Brickhouse, Lowery, & Schultz, 2000; Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Hill, Corbett, & St. Rose, 2010; Wong, 2012). Therefore, the goal of the present study was to provide insights into female middle grade students’ attitudes toward science and constructions of science identity, operationalized here as two dimensions: (a) their *beliefs about whether science is accessible to people “like them”* and (b) their *beliefs about whether science is interesting or important*. The study drew on survey data from all students attending the Lyon Academy, a small all-girls middle school designed to enhance the students’ learning, as well as interview and classroom observational data for three focal students, Effie, Mandy, and Gloria. In this section, I discuss four key findings.

First, overall survey results highlighted the complex and multi-faceted nature of science identity. Because of this complexity, students might develop strong positive beliefs related to one dimension of science identity but not another. Specifically, most Lyon Academy students indicated that science was interesting and useful, but expressed more ambivalence about its accessibility to people “like them.” Moreover, they were divided in their responses about its relevance to their lives outside of school and to meeting their future goals. Notably, none of the 12 Lyon Academy students I interviewed aspired to be a scientist. This pattern of relatively strong interest in science coupled with

a failure to see its relevance to future plans mirrors one found in the broader literature from the US and England (Archer et al., 2010; ASPIRES, 2013; Carlone, Haun-Frank & Webb, 2011). For example, it is consistent with findings from a large-scale British longitudinal study of young people's (age 10 to 14) beliefs about science and career aspirations (ASPIRES, 2013). Results from that study indicated that the young people generally held positive views of science and scientists, but did not hope to become scientists themselves. Furthermore, the researchers found that constructions of careers in science as "geeky," "brainy," and "not nurturing" conflicted with constructions of femininity, rendering such professions "unthinkable" for many girls, and particularly those from working class backgrounds (Archer et al., 2013). The present study extends these findings by focusing on girls from a known—and supportive—classroom environment where their female teacher attempted to counter many limited and noninclusive popular images and beliefs in order to create a more inclusive view of who scientists are and what they do. Yet in spite of this favorable classroom environment, the aforementioned pattern still held. This indicates that even in a classroom environment that supports girls science learning, it may be difficult to overcome popular images and cultural discourses that present a limited and noninclusive view of who scientists are. Three additional findings from comparisons across the case study students, discussed in detail below, provide more nuance that helps unpack this complexity.

First, comparisons across the cases of Effie, Mandy and Gloria suggest the importance of careful consideration of students' understandings of what it means to be a good scientist. Although they are all taught by the same teacher using the same curriculum, Effie, Mandy, and Gloria hinted at quite different understandings of what lies

at the heart of doing science. Effie presented a mentally and physically active view of science that emphasized the need to “figure out” and to work with others so that you have “more people seeing things that you don’t see.” On the other hand, Mandy described doing science in a way that emphasized novel hands-on activities, but did not make a clear link to scientific habits of mind. Finally, Gloria offered a more passive vision where being a good scientist meant “doing everything that’s expected of you.” In this world, doing science meant following directions from books that tell you exactly what to do in order to get predetermined results. Previous research has shown that different understandings of what it means to be a good scientist have important implications for students’ trajectories (Carlone, Haun-Frank & Webb, 2011; Carlone, Scott & Lowder, 2014). For example, Carlone, Scott and Lowder (2014) documented how moving from a 4th grade classroom where being a “smart science student” involved things like critical thinking, persistence, and nurturing peers (a view more aligned with Effie’s) to a 6th grade science classroom where it involved things like memorizing and compliance (a view more aligned with Gloria’s) can lead students to engage in less scientific (but more compliant) behaviors or to disaffiliate from school science entirely.

Additionally, the study confirms the role of popular conceptions of who scientists are and what they do to girls’ constructions of science identity. All three case study students reported subscribing to an equitable view of science where anyone can become a scientist as long as they like science (Effie and Mandy) or try hard (Gloria). However, Gloria also made statements that directly contradicted this assertion (“I never seen a dark skinned person doing science that much.”) and she was not the only Lyon Academy student to do so. Importantly, in this statement Gloria maintained a distinction, similar to

that observed elsewhere in the literature (Archer et al., 2010), between school science and “real” or adult science. That so many students maintain this distinction is not surprising since science as practiced in schools often differs in fundamental ways from adult science. Specifically, school science often ignores the inquiry that lies at the heart of science in favor of activities where students’ goal is to follow a set of predetermined procedures in order “to get things to work as expected” (Millar, 1998 as cited in Osborne, 2002, p. 204). However, this does raise the issue that it may be difficult for students from underrepresented groups to use themselves and their peers as models of people “like them” doing science while what happens in their classrooms remains removed from adult science.

Finally, my findings suggest the importance of recognition from others in understanding the relationship between science knowledge and science identity because one must be able to demonstrate a certain level of science knowledge in order to be recognized as the kind of person who is competent in science (i.e., develop science identity; Carlone & Johnson, 2007). In the present study, both Effie and Mandy were able to effectively exhibit their knowledge in science class. As a result, they were recognized by their teacher as above average science students and recognized themselves as good at science. In contrast, Gloria experienced more difficulty demonstrating science knowledge. She was neither recognized by her teacher nor recognized herself as someone who was good at science. The theme of frustration was salient in her interview, as was the fear of being accused of failing to pay attention. According to her, this fear actually prevented her from asking questions that might help her develop deeper understanding in science class. The present study does not include a measure of these students’ science

knowledge. However, regardless of their actual levels of science knowledge, their perceived recognition (or lack thereof) as knowledgeable and capable in science appears to play a role in their development of science identities. This finding extends Carlone and Johnson's (2007) model, based on interviews with women of color who studied science at the post-secondary level, by indicating that recognition may also be a crucial factor in promoting or hindering science identity development among girls in the middle grades.

Implications for Practice

Overall, my findings have several implications for practice. First, the complexity of science identity needs to be acknowledged in science classrooms. Research has shown how science teachers can promote affiliation with their discipline by using inclusive linguistic markers, such as “as scientists, we” (Moje, 1995; Also see Chapter 3) or creating classroom norms and expectations that give all students opportunities to participate in scientific practices (Carlone, Scott & Lowder, 2014). However, my findings taken together with findings from the broader literature indicate that attention to just one dimension of science identity might not be enough to provide students with real access to the discipline. For example, students may come to think that classroom science is interesting and fun but still not see science as a viable career option for people like them.

This disconnect between interest and future aspirations suggests the need for science instruction that engages with multiple dimensions related to science identity development as well as young peoples' everyday identities. Indeed, Archer and colleagues (2010) have argued for just such an approach:

This may point to the need to work with multiple visions of science—a position that in itself suggests a need to disrupt dominant discourses around science and

the identity of a scientist. It also impels us to consider how we might bridge the gap between children and young people's everyday identities (those that are experienced as desirable, authentic, and conveying status within their daily fields of interaction) and the identities and messages conveyed by school and "real" science (p. 636-637).

In considering what it might look like to provide students with "multiple visions of science" that disrupt popular conceptions of who scientists are, Effie provides a practical example. Jane Goodall, whom she learned about in a previous science class when they studied "different types of science," seems to have provided her with a powerful model of a woman doing science that contrasts with many noninclusive popular images and beliefs. Such real life examples may be important for expanding students' conceptions of who scientists are and what they do.

In addition, the findings regarding differences in students' understandings of what makes someone a good scientist have implications for science classrooms. Previous research has linked teachers' instructional practices to students' views of what makes someone a good scientist (e.g., Carlone, Scott & Lowder, 2014). Importantly, findings from the present study indicate that even students within the same classroom can express very different ideas about what it means to be a good scientist. Some of these views appear to be more conducive to developing a science identity (e.g., working together to figure things out) than others (e.g., following directions and not asking questions). Thus, it may be fruitful for classroom science teachers to lead discussions in which students express their understandings of what makes someone a good scientist so that they can develop a more productive common understanding of these behaviors and habits of mind.

Limitations and Directions for Future Research

It is important to acknowledge that this study involves the analyses of data from one small school serving middle graders. I chose to work at this school because it provided an interesting context to explore science identity, namely an all-female school where the teacher used language and instructional practices that actively encouraged her students to view themselves as scientists and construct a more inclusive view of who scientists are and what they do. The school is by no means representative of middle schools in the US. Thus results from this study should be taken as illuminating students' constructions of science identity within a particular context that would seem to encourage girls' development of science identities rather than generalized beyond this context. Given the relative paucity of research in this area, more research is needed to understand the complex and dynamic nature of constructions of science identity among traditionally underrepresented students, especially in the schools that the majority of such students attend, namely large, underperforming, co-educational settings.

In addition, this study draws largely on survey and interview data that present a snapshot of one moment in time. Given the dynamic nature of science identity, further longitudinal research is needed to explore the trajectories along which science identity develops. This is especially important because previous research has shown a decline in interest in science during the middle grades, followed by relatively stable interest in science after about age 14 (For a review, see Archer et al., 2010). In particular, future research should attend to the factors that appear to aid or hinder the development of science identities over time, especially for students from traditionally underrepresented groups.

Finally, while researchers have demonstrated the explanatory potential of science identity for students' engagement in science class and/or future career aspirations (e.g., Archer et al., 2010; Archer et al., 2012; Carlone, Haun-Frank & Webb, 2011; Carlone, Scott & Lowder, 2014), they have operationalized the construct in many different ways, making it difficult to compare across studies. Although a few researchers (e.g., Carlone & Johnson, 2007) have attempted to construct models of science identity grounded in the extant literature and empirical work, more work, theoretical and empirical, needs to be done on this front.

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Table 1. Summary of demographic and science identity data for three case study students.

	Effie	Mandy	Gloria
Grade	6	5	6
Race/Ethnicity	Black	Multi-Racial	Latina
Birth Country	Cameroon	US	US
Home Language(s)	Mostly English, Some French	English	Spanish, English
Eligible for Free or Reduced Price Lunch	Yes	No	Yes
Teacher Classification of Science Achievement	Above Average	Above Average	Below Average
Strength of Beliefs about Accessibility of Science	Medium	High	Low
Strength of Beliefs about How Interesting/Useful Science Is	High	Medium	Low
Career Aspirations	Gymnast, then Doctor or Surgeon	“Something Creative,” like an Author; used to want to be a Scientist	Hairstylist, Chef, Basketball Player or Mechanic
Self-Assessment of Whether Career Aspirations Are Related to Science	Yes	“Kind of”	No

^a All names are pseudonyms.

Table 2. Descriptive statistics for survey items related to Lyon Academy students' ($n=50$) beliefs about accessibility of science and interest in/importance of science.

Construct	Item	Median(IQR)	Question
<i>Accessibility of Science</i>	Q1	3(1)	How easy is it for people like you to become scientists?
	Q2	3(1)	How often are people like you who want to be scientists able to become scientists?
	Q3	4(1)	How often do things you cannot control get in the way of your understanding science?
	Q4	4(0)	How difficult do you think science is?
	Q5	2(1)	How smart do you have to be to be a scientist?
<i>Interest in and Importance of Science</i>	Q6	4(1)	How interesting do you think science is?
	Q7	4(1)	How useful do you think science is?
	Q8	3(2)	How helpful is learning science to meeting your goals for yourself?
	Q9	3(2)	How often do you use things you learn in science class outside of school?
	Q10	3(1)	How important is learning science for your future?

Note: All survey questions are on a 5-point scale.

Figure 1. Comparison of three case study students and median Lyon Academy student response for survey items related to beliefs about accessibility of science to people like them.

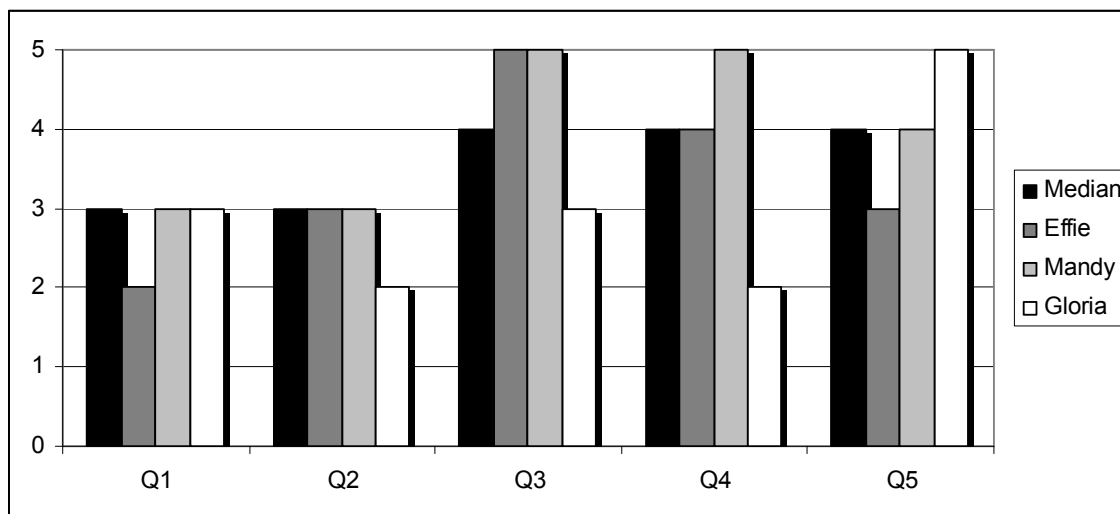
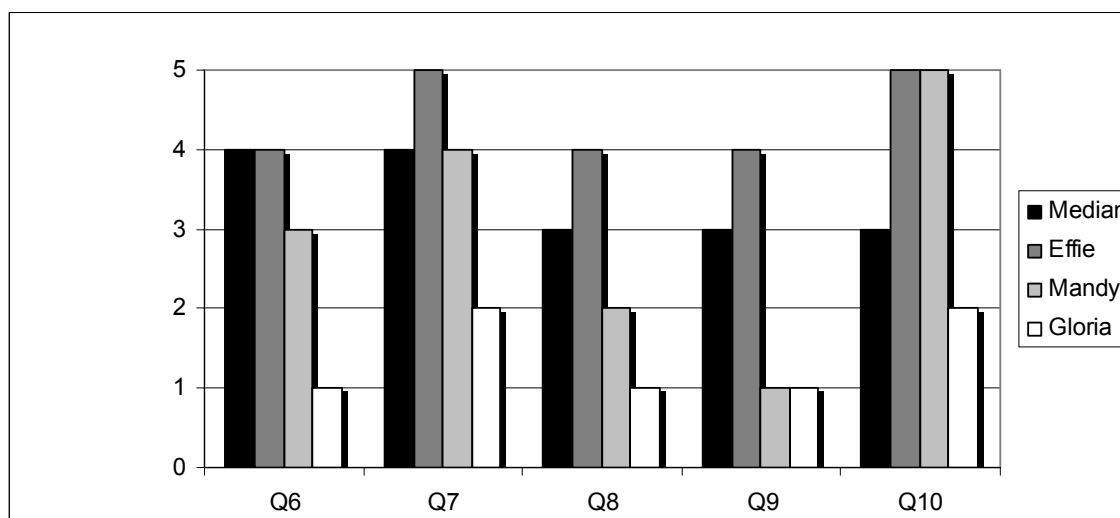


Figure 2. Comparison of three case study students and median Lyon Academy student response for survey items related to beliefs about how interesting and important science is.



Appendix A: Full Student Interview Protocol

YOUTH ASSENT

As you know, I have been observing your science class this year. One of the things I would like to learn more about is what middle schoolers like you think science is all about. Today I would like to hear your ideas about that. I would like to ask you some questions and do a reading activity with you. This will help me to learn about how to make science instruction better for other kids like you. But your participation is completely voluntary. You do not have to participate if you do not want to, and you will not be in trouble if you decide you do not want to participate.

Are you interested in participating?

I would like to video record our conversation so that I do not have to take so many notes. I will keep this video locked up and will only use it for my research. Is that okay?

At any point, we can stop. Just tell me that you would like to stop and I will let you go back to class.

PROTOCOL

WARM UP

(1) To start out, I'd like you to imagine yourself in 20 years and describe what kind of work you will be doing. Tell me about it. Is there any part of what you will be doing that is related to science?

Now I am going to start asking you some questions about science. There are no right or wrong answers, I would just like to know what you think.

PART A: SCIENTIFIC IDENTITIES

I. SCIENTISTS DOING SCIENCE

(2) First of all, I would like you to picture in your mind a scientist who is doing scientific work. Think about what the scientist is doing, where the scientist is, and what the scientist is like. I'll give you a minute to get that picture in your mind. Tell me when you are ready.

Can you tell me about what you pictured in your mind?

GENERAL PROBE IF NEED MORE INFORMATION:

- Can you tell me a little more about that?

PROBE IF NOT ALREADY COVERED:

- What is the scientist doing?
- Why is he or she doing this?
- Where is the scientist working?
- Is the scientist working with anyone else? IF YES, who else is the scientist working with?
What are they doing? IF NO, do you think the scientist ever works with anyone else?
Who is it? What do they do?
- Is there a certain type of person who usually becomes a scientist?

II. YOU DOING SCIENCE

(3) Now I want you to get a new picture in your mind. Picture yourself doing science in science class. Think about what you are doing, where you are, and how you feel. I'll give you a minute to get that picture in your mind. Tell me when you are ready.

Can you tell me about what you pictured in your mind?

GENERAL PROBE IF NEED MORE INFORMATION:

- Can you tell me a little more about that?

PROBE IF NOT ALREADY COVERED:

- What are you doing?
- Why are you doing that?
- Where are you doing it?
- Are you working with anyone else? IF YES, who else are you working with? What are they doing? IF NO, do you ever work with other people when you do science? Who is it? What do you do together?

(4) Do you like science? Why or why not?

(5) Are you good at science? Why or why not?

(6) Do you ever use the things you learn in science class outside of school? Can you give me an example?

PART B: SCIENCE-SPECIFIC WAYS OF GENERATING AND CHALLENGING KNOWLEDGE

Now I would like to talk to you a little bit more about how scientists think and what scientists do.

(7) First, I'm going to show you a bunch of pictures. I want you to take a look at them and tell me whether they show something that has to do with science or not. How do you know this is/isn't science?

(8) What makes someone a good scientist?

(9) Take a minute to think of a science experiment. It can be an experiment you did or heard about in school or it can be something you did or heard about outside of school. It can also be something you make up that you think would be an interesting experiment. Describe the experiment for me.

(9a) What could you find out by doing this experiment?

(9b) What would happen if you did this experiment and it turned out differently from what you expected?

(9c) What are some reasons why you might have gotten a different result than you expected?

(10) Imagine that two different people did the experiment you just told me about. What would happen if they disagreed about the results of an experiment?

(10a) What are some reasons why they might disagree with each other about the results of an experiment?

(10b) What should they do if they disagree?

PART C: SCIENCE-SPECIFIC WAYS OF INTERACTING WITH TEXT

The last thing I would like to talk to you about is reading science. You already read this short article for homework.

I. TEXT SPECIFIC

(11) Where should we start reading? Why?

(12) What is the next part we should read? Why?

(13) Read just to the place I have marked. What were you thinking about as you read?

(14) Who do you think wrote this? Why do you think that?

(15) The author of this text put in diagrams, pictures, and definitions. Why do you think they are there? What might we use them for?

(15a) Are they telling us the same thing or different things?

(15b) Are these all equally important for understanding what this means or is one part the most important?

(16) The author also put in titles like this and headings like this (point). Why do you think they are there? What might we use them for?

II. GENERAL

(17) What is the purpose of reading science articles like these? Why might you read this kind of article?

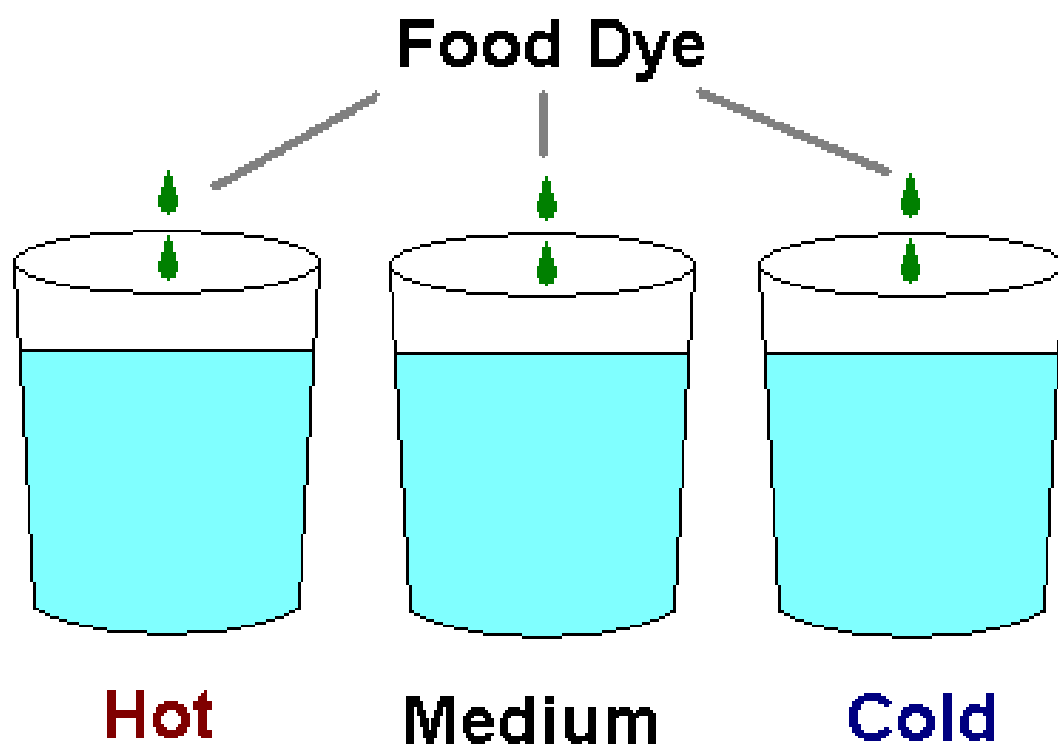
(18) If you did the experiment that the article talks about and the results were not the same as what the article said, what would you do? Why?

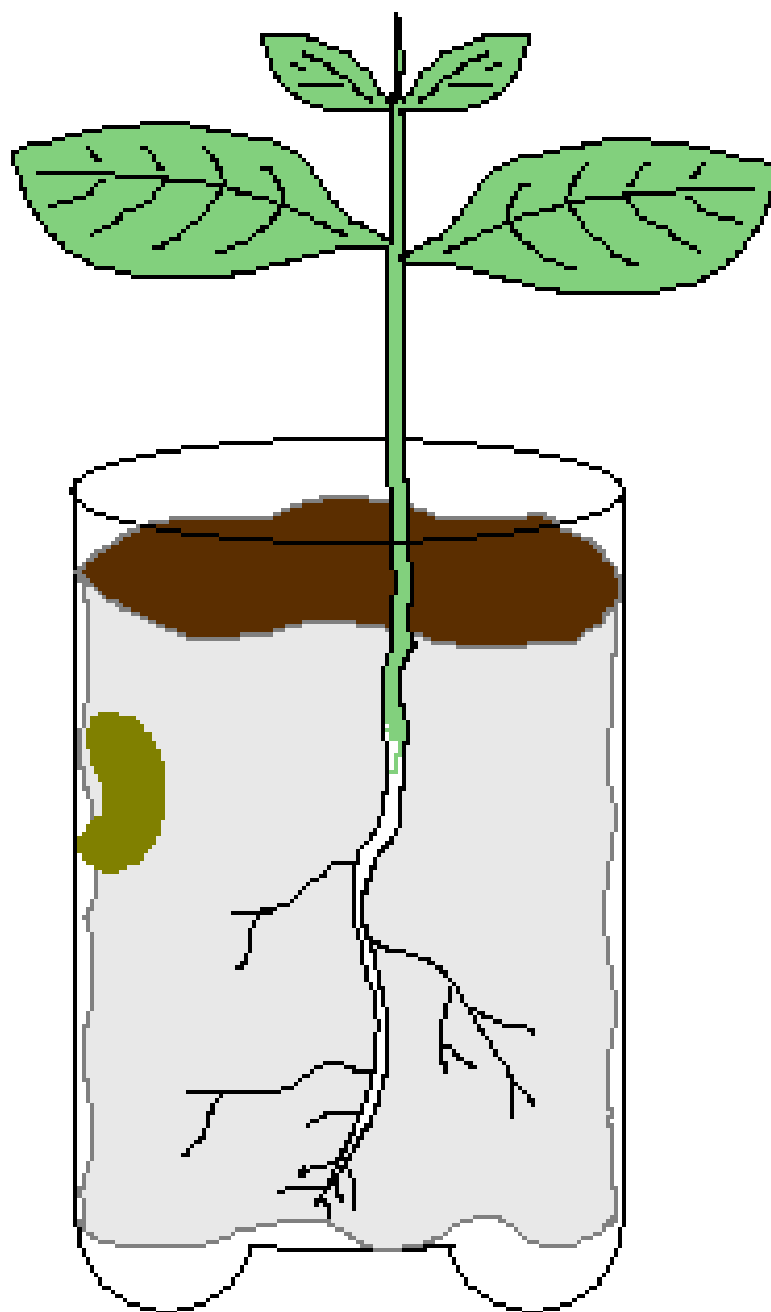
(19) Do you ever use other information (things you already have in your head) when you are reading for science? How/why?

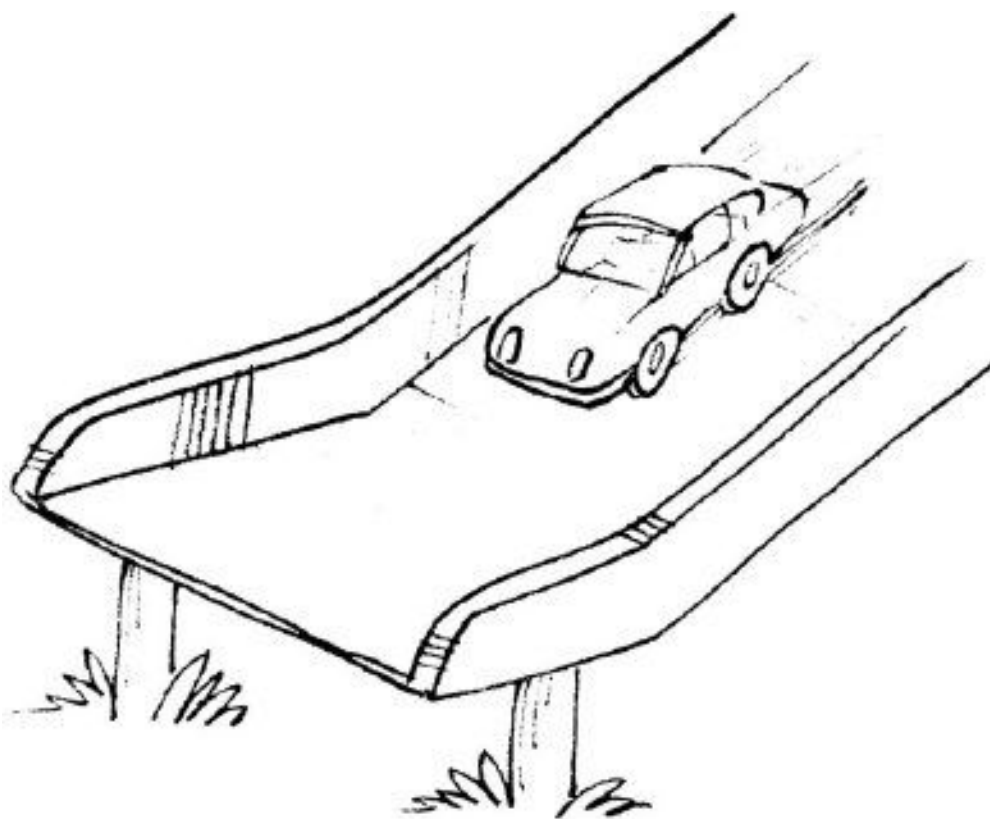
(20) What do you do when something you already know is not the same as what you read in a science article?

Images for Question 7















Appendix B: Full Student Survey Measure**SCHOOL SCIENCE SURVEY****DIRECTIONS**

As you know, I am a researcher from the Harvard Graduate School of education, who is interested in what students like you think about learning science. This information is important for helping students at your school and other schools to do better in science class. The first section asks you questions about what scientists are like and how you feel about science. The second section asks your opinion about learning new things in science. The last section asks you about reading science books and articles. Because I want to make sure that I know as much as possible about your opinions, it is important that you answer all of these questions. Please think about one question at a time and circle the answer that best matches your idea. There are no right or wrong answers. If you are unsure of your answer, just take your best guess.

Thank you for your thoughtful answers and helping me to learn more about what students think about science.

NAME _____

DATE _____

GRADE _____

Section 1: Please circle the response that best matches your opinion about what scientists are like and how you feel about science (questions 1- 15)

1. How easy is it for people like you to become scientists?

Not Easy at All	A Little Easy	Somewhat Easy	Very Easy	Extremely Easy
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2. How often are people like you who want to be scientists able to become scientists?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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3. How often do things you cannot control get in the way of your understanding science?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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4. How difficult do you think science is?

Not Difficult at All	A Little Difficult	Somewhat Difficult	Very Difficult	Extremely Difficult
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5. How often do scientists make mistakes?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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6. How smart do you have to be to be a scientist?

Not Smart at All	A Little Smart	About as Smart as Most People	Very Smart	A lot Smarter than Most People
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7. How easy is it to challenge what expert scientists say?

Not Easy at All	A Little Easy	Somewhat Easy	Very Easy	Extremely Easy
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8. How interesting do you think science is?

Not Interesting at All	A Little Interesting	Somewhat Interesting	Very Interesting	Extremely Interesting
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9. How useful do you think science is?

Not Useful at All	A Little Useful	Somewhat Useful	Very Useful	Extremely Useful
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10. How helpful is learning science to meeting your goals for yourself?

Not Helpful at All	A Little Helpful	Somewhat Helpful	Very Helpful	Extremely Helpful
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11. How often do you use things you learn in science class outside of school?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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12. How important is learning science for your future?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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13. How important is it to learn to talk like a scientist?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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14. How often do you try to talk like a scientist in science class?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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15. How often do you try to talk like a scientist even though you might not be saying it right?

Never	Once in a While	Sometimes	Most of the Time	Almost All the Time
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Section 2: Please circle the response that best matches your opinion about learning new things in science (questions 16- 30).

16. How important is evidence to learning new things in science?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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17. How useful is it to do the same science experiment more than one time?

Not Useful at All	A Little Useful	Somewhat Useful	Very Useful	Extremely Useful
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18. How important is it to test ideas in science?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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19. In science, how easy is it to prove something is true so that it never needs to be tested again?

Not Easy at All	A Little Easy	Somewhat Easy	Very Easy	Extremely Easy
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20. How often do scientists disagree with each other?

Never	Once in a While	Sometimes	Pretty Often	Most of the Time
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21. How often do scientists challenge each other's ideas?

Never	Once in a While	Sometimes	Pretty Often	Most of the Time
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22. How important is it to make sure there are no disagreements in science?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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23. How likely is it that if two scientists disagree, one of them did something wrong?

Not likely at All	A Little likely	Somewhat likely	Very likely	Extremely likely
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24. In science, how likely is it that ideas will change over time?

Not likely at All	A Little likely	Somewhat likely	Very likely	Extremely likely
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25. How important is it that scientists rethink their ideas when new evidence is found?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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26. How important is it for scientists to spend a lot of time thinking about how to design their experiments?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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27. In science, how much does an experiment's design matter for understanding the results?

Doesn't Matter at All	Matters A Little	Somewhat Matters	Matters Pretty Much	Matters a Whole Lot
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28. How often do scientists work with other people?

Never	Once in a While	Sometimes	Pretty Often	Most of the Time
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29. How important are other people's ideas to a scientist's work?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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30. In science, how important is it to know the year when an experiment was done?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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Section 3: Please circle the response that best matches your ideas about reading science books and articles (questions 31- 45).

31. In science books and articles, how important is it to look at pictures, charts, and graphs in addition to reading the words on the page?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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32. In science books and articles, how easy is it to get all of the information by reading the words but skipping over any pictures, charts, and graphs?

Not Easy at All	A Little Easy	Somewhat Easy	Very Easy	Extremely Easy
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33. When reading science books and articles, how often should you move back and forth between the words on the page and any pictures, charts, and graphs?

Never	Once in a While	Sometimes	Pretty Often	Most of the Time
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34. When reading science books and articles, how important is it to think about how what you are reading fits in with what you already know?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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35. When reading science books and articles about a topic you know a lot about, how important is it to think about the evidence that the author presents?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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36. When reading science books and articles about a topic you do not know much about, how important is it to try to learn from the text?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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37. When reading science books and articles, how important is it to think about whether you agree or disagree with what the author is saying?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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38. When reading science books and articles, how important is it to think about whether the author agrees or disagrees with other things you have read?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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39. When reading science books and articles, how important is it to think about whether the author agrees or disagrees with the ideas you already had?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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40. When reading science books and articles, how often do you think about why authors might disagree with each other?

Never	Once in a While	Sometimes	Pretty Often	Most of the Time
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41. When reading science books and articles, how important is it to use the titles and headings to decide which section to read first?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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42. When reading science books and articles, how important is it to use the titles and headings to decide which sections to read most carefully?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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43. When reading science books and articles, how important is it to pay attention to how the text is organized?

Not Important at All	A Little Important	Somewhat Important	Very Important	Extremely Important
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44. When reading science books and articles, how much does it matter who the author is?

Doesn't Matter at All	Matters A Little	Somewhat Matters	Matters Pretty Much	Matters a Whole Lot
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45. When reading science books and articles, how much does it matter when the text was written?

Doesn't Matter at All	Matters A Little	Somewhat Matters	Matters Pretty Much	Matters a Whole Lot
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VITA

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